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AGRICULTURAL RESEARCH INSTITUTE
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OF THE
ROYAL SOCIETY
OF
NEW SOUTH WALES
FOR
1923.

(INCORPORATED 1881.)

VOL. LVII.

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The Royal Society of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty Queen Victoria, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

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Authors of papers desiring illustrations are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink, so as to admit of the blocks being prepared directly therefrom, in a form suitable for photographic "process." The size of a full page plate in the Journal is 4¼ in. × 6¾ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

ERRATA.

Page 4, line 28, for 1909 read 1908.
" 9, line 30, for 48 years read 45 years.
" 50, Last citation but one should read—No. 23 "The Geology of the Eruptive and Associated Rocks of Pokolbin, New South Wales."

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I bequeath the sum of £ to the Royal Society of New South Wales, Incorporated by Act of the Parliament of New South Wales in 1881, and I declare that the receipt of the Treasurer for the time being of the said Corporation shall be an effectual discharge for the said Bequest, which I direct to be paid within calendar months after my decease, without any reduction whatsoever, whether on account of Legacy Duty thereon or otherwise, out of such part of my estate as may be lawfully applied for that purpose.

[*Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.*]

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1922		Ferguson, Andrew, 9 Martin Place, Sydney.
1920	P 1	Ferguson, Eustace William, M.B., Ch.M., 'Timbrabongie,' Gordon Road, Roseville.
1923		Fiaschi, Piero, O.B.E., M.D. (Columbia Univ.), D.D.S. (New York) M.R.C.S. (Eng.), L.R.C.P. (Lond.), 178 Phillip-street.
1881		Fiaschi, Thos., M.D., M.Ch. *Pisa*, 'The Albany,' 201 Macquarie-st.
1920		Fisk, Ernest Thomas, Wireless House, 97 Clarence-street.
1888		Fitzhardinge, His Honour Judge G. H., M.A., 'Red Hill,' Beecroft.
1922		Fleming, Edward Patrick, Under Secretary for Lands, Lands Department, Sydney.

Elected		
1921		Fletcher, Joseph James, M.A., B.Sc., 'Ravenscourt,' Woolwich Road, Woolwich.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.* L.R.C.P. *Edin.*, 'Wyoming,' Macquarie-street.
1920		Fortescue, Albert John, 'Benambra,' Loftus-street, Arncliffe.
1905		Foy, Mark, Elizabeth and Liverpool-streets.
1904		Fraser, James, C.M.G., M. INST. C.E., Chief Commissioner for Railways, Bridge-street; p.r. 'Arnprior,' Neutral Bay.
1907		Freeman, William, 'Ghyll Grange,' 50 Muston-st., Mosman.
1881		Furber, T. F., F.R.A.S., L.S., c/o Dr. R. I. Furber, 'Sunnyside,' Stanmore Road, Stanmore.
1918		Gallagher, James Laurence, M.A. *Syd.*, 'Akaroa,' Ellesmere Avenue, Hunter's Hill.
1921		Godfrey, Gordon Hay, M.A., B.Sc., Lecturer in Physics in the Technical College, Sydney; p.r. 262 Johnston-street, Annandale.
1897		Gould, The Hon. Sir Albert John, K.B., V.D., 'Eynesbury,' Edgecliff.
1922	P 2	Grant, Robert, F.C.S., Department of Public Health, 93 Macquarie-street.
1916		Green, Victor Herbert, 7 O'Connell-street.
1922	P 1	Greig, William Arthur, Mines Department, Sydney.
1899	P 1	Greig-Smith, R., D.Sc. *Edin.*, M.Sc. *Dun.*, Macleay Bacteriologist, Linnean Society's House, Ithaca Road, Elizabeth Bay. (President 1915.)
1912		Griffiths, F. Guy, B.A., M.D., Ch M., 131 Macquarie-street.
1923		Gurney, William Butler, Government Entomologist, Department of Agriculture, Sydney.
1919		Grutzmacher, Frederick Lyle, F.C.S., Church of England Grammar School, North Sydney.
1891	P 16	‡Guthrie, Frederick B., F.I.C., c/o 'Daily Mail' Office, Brisbane. (President 1903).
1919		Hack, Clement Alfred, Collins House, 360 Collins-street, Melbourne.
1880	P 5	Halligan, Gerald H., L.S., F.G.S., 97 Elphin Road, Launceston, Tasmania.
1912		Hallmann, E. F., B.Sc., 75 Hereford-street, Forest Lodge.
1892		Halloran, Henry Ferdinand, L.S., 82 Pitt-street.
1919		Hambridge, Frank, 58 Pitt-street.
1916	P 1	Hamilton, Arthur Andrew, 'The Ferns,' 17 Thomas-st., Ashfield
1912		Hamilton, Alexander G., 'Tanandra,' Hercules-st., Chatswood.
1887	P 8	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; 'Glendowan,' Glenbrook, Blue Mountains. B.M.A. Building, 30 Elizabeth-st. (President 1899, 1908).
1909		Hammond, Walter L., B.Sc., High School, Broken Hill.
1916		Hardy, Victor Lawson, 6 Dudley-street, Coogee.
1905	P 3	Harker, George, D.Sc., Lecturer and Demonstrator in Organic Chemistry in the University of Sydney.
1913	P 1	Harper, Leslie F., F.G.S., Geological Surveyor, Department of Mines, Sydney.

Elected.		
1919		Harrison, Launcelot, B.Sc., *Syd.*, B.A. *Cantab.*, Professor of Zoology in the University of Sydney.
1923		Harrison, Travis Henry, Lecturer in Entomology and Botany at the Hawkesbury Agricultural College, Richmond.
1918		Hassan, Alex. Richard Roby, c/o W. Angliss & Co. Ppty. Ltd., 64 West Smithfield, London, E.C.
1884	P 1	Haswell, William Aitcheson, M.A., D.Sc., F.R.S., Emeritus Professor of Zoology and Comparative Anatomy in the University of Sydney; p.r. 'Mimihau,' Woollahra Point.
1919		Hay, Alexander, Coolangatta, N.S.W.
1916		Hay Dalrymple-, Richard T., L.S., Chief Commissioner of Forests, N. S. Wales; p.r. Goodchap Road, Chatswood.
1914		Hector, Alex. Burnet, 481 Kent-street.
1891	P 3	Hedley, Charles, F.L.S., Australian Museum, Sydney. (President 1914.)
1916		Henderson, James, 'Dunsfold,' Clanalpine-street, Mosman.
1919		Henriques, Frederick Lester, 56 Clarence-street.
1919	P 2	Henry, Max, D.S.O., B.V.Sc., M.R.C.V.S., 'Coram Cottage,' Essex-street, Epping.
1884	P 1	Henson, Joshua B., ASSOC. M. INST. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1918		Hindmarsh, Percival, M.A., B.Sc. (Agr.), Teachers' College, The University, Sydney; p.r. 'Lurnea,' Canbarra Avenue, Greenwich.
1921	P 1	Hindmarsh, William Lloyd, B.V.Sc., M.R.C.V.S., D.V.H., Stock Branch, Department of Agriculture, Sydney.
1920		Hinds, Herbert Henry, 484 Kent-street, Sydney.
1916		Hoggan, Henry James, 'Lincluden,' Frederick-st., Rockdale.
1901		Holt, Thomas S., 'Amalfi,' Appian Way, Burwood.
1905	P 3	Hooper, George, F.T.C. *Syd.*, Assistant Superintendent, Sydney Technical College; p.r. 'Nycumbene,' Nielson Park, Vaucluse.
1920		Hordern, Anthony, c/o Messrs. A. Hordern & Sons Ltd., Brickfield Hill.
1919		Horsfall, William Nichols, M.B., B.S. *Melb.*, Lecturer and Demonstrator in Physiology in the University of Sydney.
1919		Hoskins, Arthur Sidney, Eskroy Park, Bowenfels.
1919		Hoskins, Cecil Harold, Windarra, Bowenfels.
1891	P 1	Houghton, Thos. Harry, M. INST. C.E., M. I. MECH. E., 63 Pitt-st. (President 1916),
1919		Houston, Ralph Liddle, 'Noorong,' Cooper-street, Strathfield.
1906		Howle, Walter Cresswell, L.S.A. *Lond.*, 'Lugano,' 244 Military Road, Mosman.
1913		Hudson, G. Inglis, J.P., F.C.S., 'Gudvangen,' Arden-st., Coogee.
1920		Hulle, Edward William, Commonwealth Bank of Australia.
1923		Hunter, John Irvine, M.B., Ch.M., Professor of Anatomy in the University of Sydney, 'Montrose,' Musgrave-st., Mosman.
1923	P 2	Hynes, Harold John, B.Sc., (Agr.), Walter and Eliza Hall Agricultural Research Fellow, Agricultural School, The University of Sydney.
1923		Ingram, William Wilson, M.C., M.D., Ch.B., The University, Sydney.

Elected		
1921		Jackson, Frederick Henry, c/o J. B. Jackson, B.M.A. Building 32 Elizabeth-street.
1922		Jacobs, Ernest Godfried, 'Cambria,' 106 Bland-street, Ashfield.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Chief Inspector of Mines, Department of Mines, Sydney.
1917		Jenkins, Richard Ford, Engineer for Boring, Irrigation Commission, 6 Union-street, Mosman.
1918		Johns, Morgan Jones, A.M.I.E.E. *Lond.*, M.I.E. *Aust.*, M.I.M. *Aust.*, Box 2, P.O., Mount Morgan, Queensland.
1909	P 15	Johnston, Thomas Harvey, M.A., D.Sc., F.L.S., C.M.Z.S., Professor of Zoology in the University of Adelaide.
1911		Julius, George A., B.Sc., M.E., M. I. MECH. E., Culwulla Chambers, Castlereagh-street, Sydney.

1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club, Macquarie-street.
1876	P 4	Keele, Thomas William, L.S., M.INST.C.E., 'Gladsmuir,' Rivers-street, Woollahra.
1887		Kent, Harry C., M.A., F.R.I.B.A., Dibbs' Chambers, 58 Pitt-st.
1919	P 1	Kesteven, Hereward Leighton, M.D., Ch.M., D.Sc., Bulladelah, New South Wales.
1901		Kidd, Hector, M. INST. C.E., M. I. MECH. E., Cremorne Road, Cremorne.
1896		King, Kelso, 14 Martin Place.
1923		Kinghorn, James Roy, Australian Museum, Sydney.
1920		Kirchner, William John, B.Sc., 'Clyde,' Cavendish-street, Concord West.
1919		Kirk, Robert Newby, 25 O'Connell-street.
1881	P 23	Knibbs, Sir George, Kt., C.M.G., F.S.S., F.R.A.S., L.S., Director, Commonwealth Institute of Science and Industry, Member Internat. Assoc. Testing Materials; Memb. Brit. Sc. Guild, 314 Albert-street, East Melbourne; p.r. 'Cooyal,' Sunnyside Avenue, Camberwell, Victoria. (President 1898).
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.

1911	P 3	Laseron, Charles Francis, Technological Museum.
1913		Lawson, A. Anstruther, D.Sc., F.R.S.E., F.L.S., Professor of Botany in the University of Sydney.
1920		Le Souef, Albert Sherbourne, Taronga Park, Mosman.
1916		L'Estrange, Walter William, 7 Church-street, Ashfield.
1909		Leverrier, Frank, B.A., B.Sc., K.C., 182 Phillip-street.
1883		Lingen, J. T., M.A. *Cantab.*, K.C., University Chambers, 167 Phillip-street, Sydney.
1923		Lipscomb, Alan Price, L.S., c/o Lands Office, Hay.
1906		Loney, Charles Augustus Luxton, M. AM. SOC. REFR. E., Equitable Building, George-street.

1884		MacCormick, Sir Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 185 Macquarie-street.
1887		MacCulloch, Stanhope H., M.B., Ch.M. *Edin.*, 24 College-street.

Elected		
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co., Ld., Hunter-street, Sydney.
1922		MacKay, Alexander Clarke, c/o British Consul, Harbin, Manchuria.
1923		Mackay, Iven Giffard, C.M.G., D.S.O., B.A., Student Adviser and Secretary of Appointments Board, The University, Sydney.
1921		McDonald, Alexander Hugh Earle, Department of Agriculture, Sydney.
1903		McDonald, Robert, J.P., L.S., Pastoral Chambers, O'Connell-st; p.r. 'Lowlands,' William-street, Double Bay,
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.S. *Lond.*, D.P.H. *Cantab.*, Hospital for the Insane, Gladesville.
1919		McGeachie, Duncan, M.I.M.E., M.I.E. (Aust.), M.I.M.M. (Aust.), 'Craig Royston,' Toronto, Lake Macquarie.
1919	P 1	McGlynn, William Henry, 'Koora,' Iredale Avenue, Cremorne.
1906		McIntosh, Arthur Marshall, 'Moy Lodge,' Hill-st., Roseville.
1891	P 2	McKay, R. T., L.S., M. INST. C.E., Commissioner, Sydney Harbour Trust, Circular Quay.
1880	P 9	McKinney, Hugh Giffin, M.E., Roy. Univ. *Irel.*, M. INST. C.E., Sydney Safe Deposit, Paling's Buildings, Ash-street.
1922		McLuckie, John, M.A., B.Sc., (*Glasgow*), D.Sc., (*Syd.*), Lecturer in Botany in the University of Sydney.
1901	P 1	McMaster, Colin J., L.S., 'Crona,' Keydon Avenue, Warrawee.
1916		McQuiggin, Harold G., B.Sc., Lecturer and Demonstrator in Physiology in the University of Sydney; p.r. 'Berolyn,' Beaufort-street, Croydon.
1909		Madsen, John Percival Vissing, D.Sc., B.E., Professor of Electrical Engineering in the University of Sydney.
1883	P 44	Maiden J. Henry, J.P., I.S.O., F.R.S., F.L.S., F.R.H.S., Hon. Fellow Roy. Soc. S.A.; Hon. Memb. Roy. Soc, W.A.; Netherlands Soc. for Promotion of Industry; Philadelphia College Pharm.; Southern Californian Academy of Sciences; Pharm. Soc. N.S.W.; Brit. Pharm. Conf.; Corr. Fellow Therapeutical Soc., Lond.; Corr. Memb. Pharm. Society Great Britain; Bot. Soc. Edin.; Soc. Nat. de Agricultura (Chile); Soc. d'Horticulture d'Alger; Union Agricole Calédonienne; Soc. Nat. etc., de Chérbourg; Roy. Soc. Tas.; Roy. Soc. Queensl.; Inst. Nat. Genévois; Hon. Vice-Pres. of the Forestry Society of California; Diplomé of the Société Nationale d'Acclimatation de France; Linnean Medallist, Linnean Society; N.S.W. Govt. Rep. of the "Commission Consultative pour la Protection Internat. de la Nature"; Corr. Memb. National Acclimatisation Society of France; Government Botanist and Director, Botanic Gardens, Sydney; p.r. 'Levenshulme,' Turramurra Avenue, Turramurra. (President 1896. 1911.)
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1920	P 1	Mann, Cecil William, 'Pentreath,' Fairview-street, Arncliffe.
1920		Mann, James Elliott Furneaux, Barrister at Law, 163 Phillip-street.
1908		Marshall, Frank, C.M.G., B.D.S., 151 Macquarie-street.
1914		Martin, A. H., Technical College, Sydney.
1912		Meldrum, Henry John, p.r. 'Craig Roy,' Sydney Rd., Manly.
1922		Mills, Arthur Edward, M.B., Ch.M., Dean of the Faculty of Medicine, Professor of Medicine in the University of Sydney, 139 Macquarie-street.

Elected		
1889	P 8	Mingaye, John C. H., F.I.C., F.C.S., Assayer and Analyst to the Department of Mines; p.r. Campbell-street, Parramatta.
1879		Moore, Frederick H., Union Club, Sydney.
1921		Morris, Albert, 74 Cornish-street, Railway Town, Broken Hill.
1922	P 5	Morrison, Frank Richard, Assistant Chemist, Technological Museum, Sydney; p.r. Brae-street, Waverley.
1879		Mullins, John Lane, M.A. *Syd.*, M.L.C., 'Killountan,' Double Bay.
1915		Murphy, R. K., Dr. Ing., Chem. Eng., Lecturer in Chemistry, Technical College, Sydney.
1923	P 2	Murray, Jack Keith, B.A., B.Sc. (Agr.), Principal, Queensland Agricultural College, Gatton, Queensland.
1893	P 4	Nangle, James, O.B.E., F.R.A.S., Superintendent of Technical Education, The Technical College, Sydney; p.r. 'St. Elmo,' Tupper-st., Marrickville. (President 1920.) *Vice-President.*
1917		Nash, Norman C., 'Ruanora,' Lucas Road, Burwood.
1891		‡Noble, Edward George, L.S., 8 Louisa Road, Balmain.
1920		Noble, Robert Jackson, M.Sc., B.Sc., (Agr), Ph.D., 'Lyndon,' Carrington-street, Homebush.
1919		Oakden, Frank, C.E., 33 Hunter-street.
1903		‡Old, Richard, 'Waverton,' Bay Road, North Sydney.
1921		Olding, George Henry, 'Tufra,' Napier-street, Drummoyne.
1913		Ollé, A. D., F.C.S., 'Kareema,' Charlotte-street, Ashfield.
1896		Onslow, Col. James William Macarthur, B.A., LL.B., 'Gilbulla,' Menangle.
1917		Ormsby, Irwin, 'Caleula,' Allison Road, Randwick.
1891		Osborn, A. F., ASSOC. M. INST. C.E., Water Supply Branch, Sydney, 'Uplands,' Meadow Bank, N.S.W.
1921	P 2	Osborne, George Davenport, B.Sc., Demonstrator in Geology in the University of Sydney; p.r. 'Belle-Vue,' Kembla-st., Arncliffe.
1920		Paine, William Horace, State Abattoirs, Homebush Bay, N.S.W.
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.
1921		Parkes, Varney, Royal Chambers, Castlereagh-street.
1920	P 22	Penfold, Arthur Ramon, F.C.S., Economic Chemist, Technological Museum, Harris-street, Ultimo.
1899		Peterson, T. Tyndall, F.C.P.A., E.S. & A. Bank Building, King and George-streets.
1918		Petrie, James Matthew, D.Sc., F.I.C., Research Fellow of the Linnean Society in Biochemistry, The University, Sydney.
1909	P 2	Pigot, Rev. Edward F., S.J., B.A., M.B. *Dub.*, Director of the Seismological Observatory, St. Ignatius' College, Riverview.
1879	P 8	Pittman, Edward F., ASSOC. R.S.M., L.S., 'St. Ives,' Toorak Road, South Yarra, Melbourne.
1881		Poate, Frederick, F.R.A.S., L.S., 'Clanfield,' 50 Penkivil-street, Bondi.

Elected		
1919		Poate, Hugh Raymond Guy, M.B., Ch. M. *Syd.*, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1917		Poole, William, M.E., (Civil, Min. and Met.) *Syd.*, M. INST. C.E., M.I.M.M., M.I.E., Aust., M.Am. I.M.E., M. Aust. I. M.M., L.S., 906 Culwulla Chambers, Castlereagh-street.
1896		Pope, Roland James, B.A., *Syd.*, M.D., C.M., F.R.C.S., *Edin.*, 185 Macquarie-street.
1910		Potts, Henry William, F.L.S., F.C.S., c/o Lindley Walker & Co., Ltd., Mark Lane, Sussex-street, Sydney.
1921	P 2	Powell, Charles Wilfrid Roberts, A.I.C., c/o Colonial Sugar Refining Co., O'Connell-street
1918		Powell, John, 170-2 Palmer-street.
1919		Pratten, Herbert E., M.H.R., 26 Jamieson-street.
1918		Priestley, Henry, M.D., Ch. M., B.Sc., Associate-Professor of Physiology in the University of Sydney.
1893		Purser, Cecil, B.A., M.B., Ch.M. *Syd.*, 193 Macquarie-street.
1912	P 2	Radcliff, Sidney, F.C.S., Department of Chemistry, The University of Sydney
1922		Raggatt, Harold George, B.Sc., Lord-street, Roseville.
1919	P 3	Ranclaud, Archibald Boscawen Boyd, B.Sc., B.E., Lecturer in Physics, Teachers' College, The University, Sydney.
1916	P 5	Read, John, M.A., Ph D., B.Sc., Professor of Organic Chemistry at St. Andrew's University of Scotland.
1923		Reid, Cicero Augustus, 14 Mount-street, Coogee.
1909		Reid, David, 'Holmsdale,' Pymble.
1914		Rhodes, Thomas, 'High Coombe,' Carlingford.
1920		Richardson, John James, A.M.I.E.E. *Lond.*, 'Kurrawyba,' Upper Spit Road, Mosman.
1921		Robertson, Frederick Arnold, Science Master, Sydney C. of E. Grammar School, North Sydney.
1915		Ross, A. Clunies, B.Sc., c/o G. R. W. McDonald, 32 Elizabeth-st.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, 225 Macquarie-st.
1895	P 1	Ross, Herbert E., Equitable Building, George-street.
1897		Russell, Harry Ambrose, B.A., c/o Sly and Russell, 369 George-street; p.r. 'Mahuru,' Park Road, Bowral.
1907		Ryder, Charles Dudley, Box 1934 G.P.O. Sydney.
1922		Sandy, Harold Arthur Montague, 326 George-street.
1917		Sawkins, Dansie T., M.A., 'Brymedura,' Kissing Point Road, Turramurra.
1920		Sawyer, Basil, B.E., 'Birri Birra,' The Crescent, Vaucluse.
1920		Scammell, Rupert Boswood, B.Sc., *Syd.*, 18 Middle Head Road, Mosman.
1913		Scammell, W. J., Mem. Pharm. Soc. *Grt. Brit.*, 18 Middle Head Road, Mosman.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., Associate-Professor of Chemistry in the University of Sydney.
1919		Sear, Walter George Lane, c/o J. Kitchen & Sons, Ingles-st., Port Melbourne.
1923		Seddon, Herbert Robert, D.V.Sc., Director, Veterinary Research Station, Glenfield.

Elected		
1921		Sellers, Alfred Edward Oswald, M.I.M.E., M.A.I.E., 'Strathmere,' Bellambi.
1904	P 1	Sellors, Richard P., B.A. *Syd.*, 'Mayfield,' Wentworthville.
1918		Sevier, Harry Brown, c/o Lewis Berger and Sons (Aust.) Ltd., 38a Pitt-street.
1917		Sibley, Samuel Edward, Mount-street, Coogee.
1900		Simpson, R. C., Lecturer in Electrical Engineering, Technical College, Sydney.
1910		Simpson, William Walker, 'Abbotsford,' Leichhardt-street, Waverley.
1882		Sinclair, Eric, M.D., C.M. *Glas.*, Inspector-General of Insane, 9 Richmond Terrace, Domain; p.r. 'Broomage,' Kangaroo-street, Manly.
1893	P 62	Smith, Henry G., F.C.S., 'Dunbourne,' Shirley Road, Roseville. (President 1913.)
1916		Smith, Stephen Henry, Under Secretary and Director of Education, Department of Education, Sydney.
1922		Smith, Thomas Hodge, Australian Museum, Sydney.
1919		Southee, Ethelbert Ambrook, O.B.E., M.A., B.Sc., Principal, Hawkesbury Agricultural College, Richmond, N.S.W.
1921		Spencer-Watts, Arthur, 'Araboonoo,' Glebe-street, Randwick.
1917		Spruson, Wilfred Joseph, Daily Telegraph Building, King-st.
1916		Stephen, Alfred Ernest, F.C.S., 801 Culwulla Chambers, 67 Castlereagh-street, Sydney.
1921		Stephen, Henry Montague, B.A., LL.B., 167 Phillip-street
1914		Stephens, Frederick G. N., F.R.C.S., M.B., Ch.M., 13 Dover Road, Rose Bay.
1920	P 1	Stephens, John Gower, B.Sc., St. Andrew's College, The University, Sydney.
1913		Stewart, Alex. Hay, B.E., 165 Wardell Road, Dulwich Hill.
1900		Stewart, J Douglas, B.V.Sc., M.R.C.V.S., Professor of Veterinary Science in the University of Sydney; 'Berelle,' Homebush Road, Strathfield.
1903		Stoddart, Rev. A. G., The Rectory, Manly.
1909		Stokes, Edward Sutherland, M.B. *Syd.*, F.R.C.P. *Irel.*, Medical Officer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1916	P 1	Stone, W. G., Assistant Analyst, Department of Mines, Sydney.
1919		Stroud, Sydney Hartnett, F.I.C., Lecturer in Pharmacy in the University of Sydney.
1918		Sullivan, Herbert Jay, c/o Lewis Berger and Sons (Aust.) Ltd., Rhodes.
1920		Sulman, John, Warrung-st., McMahon's Point, North Sydney.
1918		Sundstrom, Carl Gustaf, c/o Federal Match Co., Park Road, Alexandria.
1901	P 10	Sussmilch, C. A., F.G.S., Principal of the Technical College, Newcastle, N.S.W. (President 1922.) *Vice-President.*
1919		Sutherland, George Fife, A.R.C.Sc., *Lond.*, Assistant-Professor in Mechanical Engineering, in the University of Sydney.
1920		Sutton, Harvey, O.B.E., M.D., D.P.H. *Melb*, B.Sc. *Oxon.*, 'Lynton,' Kent Road, Rose Bay.
1919		Swain, Herbert John, B.A. *Cantab.*, B.Sc, B.E. *Syd.*, Lecturer in Mechanical Engineering, Technical College, Sydney.

Elected		
1917		Tate, Herbert, Bridge Road, Stanmore.
1915	P 2	Taylor, Harold B., B.Sc., Kenneth-street, Longueville.
1893		‡Taylor, James, B.Sc., A.R.S.M. 'Cartref,' Brierly-st., Mosman.
1921	P 2	Taylor, John Kingsley, 16 Ferrier-street, Rockdale.
1905		Taylor, John M., M.A., LL.B. *Syd.*, 'Woonona,' 43 East Crescent-street, McMahon's Point, North Sydney.
1921	P 2	Taylor, Thomas Griffith, B.A., D.Sc., B.E., Associate-Professor of Geography in the University of Sydney.
1920		Tebbutt, Arthur Hamilton, B.A., M.B., D.P.H., 185 Macquarie-st.
1899		Teece, R., F.I.A., F.F.A., Wolseley Road, Point Piper.
1923		Thomas, David, B.E., M.I.M.M., F.G.S., 15 Clifton Avenue, Burwood
1878		Thomas, F. J., 'Lovat,' Nelson-street, Woollahra.
1919		Thomas, John, L.S., Chief Mining Surveyor, Mines Department Sydney; p.r. 'Remeura,' Pine and Harrow Roads, Auburn.
1913		Thompson, Joseph, M.A., LL.B., Vickery's Chambers, 82 Pitt-st.
1919		Thorne, Harold Henry, B.A. *Cantab.*, B.Sc. *Syd.*, Lecturer in Mathematics in the University of Sydney; p.r. Rutledge-st., Eastwood.
1916		Tilley, Cecil E., B.Sc., The Sedgwick Museum, The University of Cambridge, Cambridge, England.
1916		Tillyard, Robin John, M.A., D.Sc., F.L.S., F.E.S., Biological Branch, Cawthron Institute, Nelson, New Zealand.
1923		Timcke, Edward Waldemar, Meteorologist, Weather Bureau, Sydney.
1923		Tindale, Harold, Works Engineer, c/o Australian Gas-Light Co., Mortlake.
1923		Toppin, Richmond Douglas, A.I.C., Parke Davis & Co., Roseberry.
1879		Trebeck, P. C., 'Banavie,' Bowral.
1900		Turner, Basil W., A.R.S.M., F.C.S., Victoria Chambers, 83 Pitt-st.
1919	P 4	Turner, Eustace Ebenezer, B.A. *Cantab.*, D.Sc. *Lond.*, A.I.C., East London College, Mile End Road, London, E. I.
1916		Valder, George, J.P., Under Secretary and Director, Department of Agriculture, Sydney.
1890		Vicars, James, M.E., Memb. Intern. Assoc. Testing Materials; Memb. B. S. Guild; Challis House, Martin Place.
1921		Vicars, Robert, Marrickville Woollen Mills, Marrickville.
1892		Vickery, George B., 78 Pitt-street.
1903	P 5	Vonwiller, Oscar U., B.Sc., Professor of Physics in the University of Sydney. *Hon. Secretary.*
1919		Waley, Robert George Kinloch, 63 Pitt-street.
1910		Walker, Charles, 'Lynwood,' Terry Road, Ryde.
1910		Walker, Harold Hutchison, Vickery's Chambers, 82 Pitt-st.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1919	P 1	Walkom, Arthur Bache, D.Sc. Linnean Society's House, 23 Ithaca Road, Elizabeth Bay.
1903		Walsh, Fred., J.P., Consul-General for Honduras in Australia and New Zealand; For. Memb. Inst. Patent Agents, London; Patent Attorney Regd. U.S.A.; Memb. Patent Law Assoc., Washington; Regd. Patent Attorn. Comm. of Aust.; Memb. Patent Attorney Exam. Board Aust.; George and Wynyard-streets; p.r. 'Walsholme,' Centennial Park, Syd.

Elected		
1901		Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1918		Ward, Edward Naunton, Superintendent of the Botanic Gardens, Sydney.
1913	P 4	Wardlaw, Hy. Sloane Halcro, D.Sc. *Syd.*, Lecturer and Demonstrator in Physiology in the University of Sydney.
1922		Wark, Blair Anderson, V.C., D.S.O., M.I.Q.C., c/o Thompson and Wark, T. & G. Building, Elizabeth-street; p.r. 'Braeside,' Zeta-street, Lane Cove, Sydney.
1883	P 17	Warren, W. H., LL.D., WH. SC., M. INST. C.E., M. AM. SOC. C.E., Member of Council of the International Assoc. for Testing Materials, Professor of Engineering in the University of Sydney. (President 1892, 1902.)
1921		‡Waterhouse, Gustavus Athol, B.Sc., B.E., F.E.S., Royal Mint, Macquarie-street. *Hon. Secretary.*
1919		Waterhouse, Lionel Lawry, B.E. *Syd.*, Lecturer and Demonstrator in Geology in the University of Sydney.
1919	P 2	Waterhouse, Walter L., M.C., B.Sc. (*Agr.*), 'Cairnleith,' Archer-street, Chatswood.
1919		Watkin-Brown, Willie Thomas, 24 Brown's Road, Kogarah.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, University Club, Castlereagh-street.
1910		Watson, James Frederick, M.B., Ch.M., 'Midhurst,' Woollahra.
1911		Watt, Robert Dickie, M.A., B.Sc., Professor of Agriculture in the University of Sydney.
1920	P 8	Welch, Marcus Baldwin, B.Sc., A.I.C., Economic Botanist, Technological Museum.
1907	P 1	Welch, William, F.R.G.S., 'Roto-iti,' Boyle-street, Mosman.
1920	P 1	Wellish, Edward Montague, M.A., Lecturer in Applied Mathematics in the University of Sydney.
1921		Wenholz, Harold, 29 Palace-street, Petersham.
1881		‡Wesley, W. H., London.
1922		Whibley, Harry Clement, 39 Moore-street, Leichhardt.
1909	P 3	White, Charles Josiah, B.Sc., Lecturer in Chemistry, Teacher's College.
1918		White, Edmond Aunger, M.A.I.M.E., c/o Electrolytic Refining and Smelting Co. of Australia Ltd., Port Kembla, N.S.W.
1892		White, Harold Pogson, F.C.S., Assistant Assayer and Analyst, Department of Mines; p.r. 'Quantox,' Park Road, Auburn.
1923		Whitehouse, Frank, B.V.Sc, (Syd.) 'Dane Bank,' Albyn Road, Strathfield.
1921		Willan, Thomas Lindsay, B.Sc., Geological Survey, Department of Mines, Sydney.
1920		Williams, Harry, A.I.C., c/o Rosebery Lanolines Pty. Ltd., Arlington Mills, Botany.
1917		Willington, William Thos., O.B.E., King-street, Arncliffe.
1923		Wilson, Stanley Eric, 'Chatham,' James-street, Manly.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1906	P 8	Woolnough, Walter George, D.Sc., F.G.S., Florence-st., Killara.
1916		Wright, George, c/o Farmer & Company, Pitt-street.
1917		Wright, Gilbert, Lecturer and Demonstrator in Agricultural Chemistry in the University of Sydney.
1921		Yates, Guy Carrington, 184 Sussex-street.
1916		Youll, John Gibson, Water Conservation and Irrigation Commission, Leeton, N.S.W.

HONORARY MEMBERS.

Limited to Twenty.

M.—Recipients of the Clarke Medal.

Elected.		
1914		Bateson, W. H., M.A., F.R.S., Director of the John Innes Horticultural Institution, England, The Manor House, Merton, Surrey, England.
1918		Chilton, Charles, M.A., D.Sc., M.B., C.M.. etc., Professor of Biology, Canterbury College, Christchurch, N.Z.
1911		Hemsley, W. Botting, LL.D. (*Aberdeen*), F.R.S., F.L.S., Formerly Keeper of the Herbarium, Royal Gardens, Kew; Korresp. Mitgl. der Deutschen Bot. Gesellschaft; Hon. Memb. Sociedad Mexicana de Historia Natural; New Zealand Institute; Roy. Hort. Soc., London; 16 Osborne Road, Broadstairs, Kent, England.
1914		Hill, James P., D.Sc., F.R.S., Professor of Zoology, University College, London.
1908		Kennedy, Sir Alex. B. W., Kt., LL.D., D. ENG., F.R.S., Emeritus Professor of Engineering in University College, London, 17 Victoria-street, Westminster, London S.W.
1908	P 57	*Liversidge, Archibald, M.A., LL.D., F.R.S., Emeritus Professor of Chemistry in the University of Sydney, 'Fieldhead,' George Road, Coombe Warren, Kingston. Surrey, England. (President 1889, 1900.)
1915		Maitland, Andrew Gibb, F.G.S., Government Geologist of Western Australia.
1912		Martin, C. J., C.M.G., D.Sc, F.R.S., Director of the Lister Institute of Preventive Medicine, Chelsea Gardens, Chelsea Bridge Road, London, S.W.I.
1894	M	Spencer, Sir W. Baldwin, K.C.M.G., M.A., D.Sc., F.R.S., Emeritus Professor of Biology in the University of Melbourne.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., LL.D., Sc.D., F.R.S., The Ferns, Witcombe, Gloucester, England.
1915		Thomson, Sir J. J., O.M., D.Sc., F.R.S., Nobel Laureate, Master of Trinity College, Cambridge, England.
1921		Threlfall, Sir Richard, K.B.E., M.A., F.R.S., lately Professor of Physics in the University of Sydney, 'Oakhurst,' Church Road, Edgbaston, Birmingham, England.
1922		Wilson, James T., M.B., Ch.M. *Edin.*, F.R.S., Professor of Anatomy in the University of Cambridge, England.

*** Retains the rights of ordinary membership. Elected 1872.**

OBITUARY 1923-24.

Davidson, Sir Walter (Vice-Patron)

Ordinary Members.

1885		**Deane, Henry**
1916		**Dixon, Jacob R. L.**
1876		**Docker, Ernest Brougham**
1899		**Henderson, James**
1914		**Kemp, William E.**
1906		**Lee, Alfred**
1905		**Miller, James Edward.**

AWARDS OF THE CLARKE MEDAL.

Established in memory of

The Revd. WILLIAM BRANWHITE CLARKE, M.A., F.R.S., F.G.S., etc.,

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia. The prefix * indicates the decease of the recipient.

Awarded	
1878	*Professor Sir Richard Owen, K.C.B., F.R.S.
1879	*George Bentham, C.M.G., F.R.S.
1880	*Professor Thos. Huxley, F.R.S.
1881	*Professor F. M'Coy, F.R.S., F.G.S.
1882	*Professor James Dwight Dana, LL.D.
1883	*Baron Ferdinand von Mueller, K.C.M.G., M.D., Ph.D., F.R.S., F.L.S.
1884	*Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S.
1885	*Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S.
1886	*Professor L. G. De Koninck, M.D.
1887	*Sir James Hector, K.C.M.G., M.D., F.R.S.
1888	*Rev. Julian E. Tenison-Woods, F.G.S., F.L.S.
1889	*Robert Lewis John Ellery, F.R.S., F.R.A.S.
1890	*George Bennett, M.D., F.R.C.S. *Eng.*, F.L.S., F.Z.S.
1891	*Captain Frederick Wollaston Hutton, F.R.S., F.G.S.
1892	Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., LL.D., Sc. D., F.R.S., F.L.S., late Director, Royal Gardens, Kew.
1893	*Professor Ralph Tate, F.L.S., F.G.S.
1895	*Robert Logan Jack, LL.D., F.G.S., F.R.G.S.
1895	*Robert Etheridge, Jnr.
1896	*The Hon. Augustus Charles Gregory, C.M.G., F.R.G.S.
1900	*Sir John Murray, K.C.B., LL.D., Sc. D., F.R.S.
1901	*Edward John Eyre.
1902	*F. Manson Bailey, C.M.G., F.L.S.
1903	*Alfred William Howitt, D.Sc., F.G.S.
1907	Walter Howchin, F.G.S., University of Adelaide.
1909	Dr. Walter E. Roth, B.A., Pomeroon River, British Guiana, South America.
1912	*W. H. Twelvetrees, F.G.S.
1914	A. Smith Woodward, LL.D., F.R.S., Keeper of Geology, British Museum (Natural History) London.
1915	Professor W. A. Haswell, M.A., D.Sc., F.R.S., The University, Sydney.
1917	Professor Sir Edgeworth David, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., The University, Sydney.
1918	Leonard Rodway, C.M.G., Honorary Government Botanist, Hobart, Tasmania.
1920	*Joseph Edmund Carne, F.G.S.
1921	Joseph James Fletcher, M.A., B.Sc., 'Ravenscourt,' Woolwich.
1922	Richard Thomas Baker, The Avenue, Cheltenham.
1923	Sir W. Baldwin Spencer, K.C.M.G., M.A., D.Sc., F.R.S., National Museum, Melbourne.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

Money Prize of £25.

Awarded.

1882 John Fraser, B.A., West Maitland, for paper entitled 'The Aborigines of New South Wales.'

1882 Andrew Ross, M.D., Molong, for paper entitled 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper entitled 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper entitled 'The Tin deposits of New South Wales.'

1887 Jonathan Seaver, F.G.S., Sydney, for paper entitled 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.'

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper entitled 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for paper entitled 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.'

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper entitled 'The Australian Aborigines.'

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper entitled 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper entitled 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper entitled the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper entitled 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, D.Sc., M.B., F.R.S., Sydney, for paper entitled 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper entitled 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

PRESIDENTIAL ADDRESS.

By C. A. SUSSMILCH, F.G.S.

With Plate I, and Text Figures.

[*Delivered to the Royal Society of N. S. Wales, May 2, 1923.*]

Another year in the history of this Society has passed by, a year of satisfactory endeavour and progress, but without any happening of an outstanding nature. The number and quality of the papers read has been quite up to that of recent years, while the attendance of members, both at the general meetings and at the sectional meetings, has been well maintained. The number of members remains about the same, the number elected during the year just about equalling the number lost by death and resignation. In this respect, the position is not so satisfactory as one could wish; with the large increase which is yearly taking place in the population of this city, we might surely expect to see something like a corresponding increase in our membership. War conditions have undoubtedly directed the minds and energies of many in other directions; but conditions have now so far become normal again that this reason should no longer apply. If the work of the Society, including the adequate maintenance of its library, is to be efficiently carried out, a larger revenue than we now possess is essential; an increased membership would help materially in this direction.

One would like also to see a larger number of the younger generation who have had a scientific training, entering the field of original research, than is at present the case. The amount of important research work waiting to be done in Australia is simply enormous, but the number of research workers remains deplorably few. Let us, for example, consider that highly important branch of research, Anthropology: for many years past, the amount of research work done in this subject in this State has been so small as to be almost negligible. Besides the problem of our own aborigines, there is an immense field of work awaiting the anthropological investigator in the neighbouring Pacific Islands. Some of these islands are now being administered by the Australian Commonwealth, and surely one of the most important factors in their successful administration should be to have as complete a knowledge of the inhabitants as is possible. The first step in the direction of obtaining this knowledge should be the preparation of a definite, well-thought-out, and comprehensive programme of anthropological research. The preparation of such a programme is well worth the attention of this Society in the immediate future. Much has been achieved in the past in this field by the efforts of individual investigators, but the time has now arrived for a more comprehensive scheme of anthropological investigation for these islands, with each section of the work adequately provided for, and all sections properly co-ordinated. There is also a pressing need for scientific research in these Pacific Islands in all other branches of science, but particularly in geography, geology, botany, and zoology. It is sincerely to be hoped that one of the results of the forthcoming Pan-Pacific Science Congress will be to stimulate interest and bring about increased attention to the scientific problems of our Pacific possessions. This Society might well devote some of its energies to these problems, both in the direction of working up interest in these matters and of preparing comprehensive programmes of research.

The Clarke Memorial Medal has this year been awarded to Sir W. Baldwin Spencer for his very eminent services in the cause of science generally, and particularly for the great work he has done in the subject of Australian Anthropology.

This evening, I have much pleasure, on behalf of the Australasian Association for the Advancement of Science, in presenting the Mueller Memorial Medal to Mr. J. H. Maiden, F.R.S., F.L.S., for his eminent services in the cause of Australian Botany. I am sure that you will agree with me that this medal has never been more worthily bestowed. It was with very great regret that your Council acquiesced in Mr. Maiden's request that he should not be nominated for the Council for the coming year; Mr. Maiden has been a member of the Council for the past 33 years and I would like to take this opportunity of testifying to the very valuable and unselfish service he has rendered to this Society during that time.

It is pleasing also to note that another member of our Council has been honored. I refer to Mr. E. C. Andrews, who has been made an Honorary Member of the Washington Academy of Sciences.

It is a matter for sincere regret that we have lost nine members by death during the past year, viz.:—Prof. J. A. Pollock and Messrs. A. L. McLean, J. E. Carne, A. H. Belfield, W. G. Jira, C. O. Hamblin, Dugald Thompson, J. T. Walker, and Albert Bond.

ARCHIBALD LANG McLEAN, M.C., B.A., M.D., elected a Member of this Society in 1917, died at the Royal Prince Alfred Hospital on Saturday, 13th May, 1922, at the age of 37 years. Dr. McLean, who was born in Sydney in 1885, received his early education at Fort Street School, and then proceeded to the Sydney University. Here he obtained the B.A. degree in 1906, and the M.B. and Ch.M. degrees in 1910. Upon leaving the University, he was appointed resident medical officer at Lewisham Hospital, and subsequently at the Coast Hospital, Little Bay.

In 1911, Dr. McLean joined the Australasian Antarctic Expedition as surgeon-in-chief and bacteriologist, and proceeded to Antarctica, where he remained with the Expedition for two years. He rendered very valuable service both to the Expedition and to the cause of science, and later collaborated with his leader, Sir Douglas Mawson, in producing "The Home of the Blizzard," an account of the Expedition. He was also the author of a work on "Bacteriological and Other Researches," published by the New South Wales Government Printer in 1919.

When the war broke out, the late Dr. McLean was in England, and joining the R.A.M.C., was appointed to the Black Watch Regiment as surgeon. Owing to illness, he was discharged in 1916, and returned to Australia. The following year he joined the A.I.F., with whom he served in Egypt and France. During his period on active service, he gained a high reputation for gallantry and devotion to duty, was mentioned in despatches, and was awarded the Military Cross. He was twice gassed. He was an assistant collector in the compilation of the Medical History of the War (Australia), and after his return was appointed medical officer in charge of the Red Cross farm-colony at Beellangera. In 1921 he was awarded the M.D. degree of Sydney University. His untimely death is a great loss to science.

Prof. James Arthur Pollock, d.sc., f.r.s., one of the Honorary Secretaries of this Society, died after a short illness on the 24th May, 1922, at the age of fifty-seven years. He was elected a Member of this Society in the year 1887, became a Member of Council in 1909, and two years later was elected to the position of Hon. Secretary, a position he held until his death. Professor Pollock was born in or near Cork, Ireland, and was educated at the Manchester Grammar School and the Royal University of Ireland, where he took the engineering degree. He arrived in Sydney in the year 1884, and obtained an appointment at the Sydney Observatory, but soon gave this up in order to enter as a student at the Sydney University. He obtained the B.Sc. degree in 1889, obtaining the University medal for physics, and in the following year he was appointed demonstrator of physics, under Prof. R. Threlfall. Upon Prof. Threlfall's retirement in 1899, J. A. Pollock succeeded to the professorship, which he held up to the time of his death. He was President of Section A of the Australasian Association for the Advancement of Science in 1909, and was elected a Fellow of the Royal Society of London in 1916.

When the Australian Mining Battalion was formed for service in France in 1915, Prof. Pollock joined with the rank of Captain. Upon arrival in France, he was placed in charge of the school for training officers in "listening" underground by means of geophones and other listening devices. Later, when this work was finished, he was moved to Farnborough in England, where he carried out important research work on aeroplane navigation problems. Here he was promoted to the rank of Major. Prof. Pollock's published research work includes some twenty papers, including research on (a) the relations between the geometrical constants of a conductor and the wavelength of the electromagnetic radiation obtained from it, (b) specific inductive capacity of a sheet of glass at high frequency, (c) the application of the ionic theory of conduction to the carbon arc, (d) investigation of the ions of the atmosphere, etc.

Professor Pollock was a member of the Royal Society of New South Wales for thirty-five years, and during this long period became endeared to all those with whom he came in contact. The essential qualities which contributed so largely towards ensuring him the affection and esteem of his colleagues were his inherently modest and courteous nature, his strict integrity, and his very great ability. He had a very high sense of duty, and could be very firm when the occasion demanded it. He contributed twelve papers to the Royal Society of New South Wales, in addition to his numerous publications elsewhere. His duties as Honorary Secretary of this Society included the charge of the Society's library, and the editing of the Society's volume. He was actuated in retaining his position on the Council purely from his desire to assist scientific effort and to serve the Society to which he had for so many years belonged. He always avoided anything which might result in drawing attention to himself, and, although on several occasions he was pressed to accept the Presidency of the Society, he always courteously but firmly declined to accede to the request. Some estimate of the place he had won in the hearts of members may be gleaned from the following resolution passed by the Council at the meeting following his death, and which reads as follows:—

> Members of the Council of the Royal Society of New South Wales desire to place on record their profound sorrow at the death of their dear colleague, Professor J. A. Pollock, and to express their high appreciation of his eminent service in the cause of science, and of his personal, most valuable, and unselfish work for this Society.

Professor Pollock was one of the founders of the Australian National Research Council in 1919, and took a very active part in all its doings. He was one of the original members of the Council and also of its Executive Committee.

JOSEPH E. CARNE, late Government Geologist, who died on July 23rd last, had been a member of this Society for 13 years, having been elected in 1909. He was born in the Riverina District of New South Wales in 1855, and was trained in his youth as a pastoralist. He spent some of his early years droving cattle in Central Australia, along the Diamantina and Cooper Rivers. Becoming almost blinded by sandy-blight, he was forced to give up this life, and came on to Sydney. Here he came under the notice of the late C. S. Wilkinson, then Government Geologist, who found him a position on the Geological Survey staff in March, 1879. Later he became mineralogist to the Survey and Curator of the Geological Museum, and was largely responsible for getting together the fine collections of minerals sent from this State to the Melbourne International Exhibition of 1888, and that held at Chicago in 1893. Later, Mr. Carne took up the position of Geological Surveyor, and in 1916 was promoted to the position of Government Geologist, a position which he held until his retirement in 1920.

While on the Geological Survey staff of this State, he made many valuable additions to our knowledge of its geology and mineral resources. His notable works include: (a) Memoir on the Kerosene Shale Deposits of New South Wales; (b) Geology of the Western Coalfield of New South Wales; (c) Mineral Resources Series on New South Wales deposits of copper, tin, limestone, mercury, chrome iron ore, antimony, etc. In 1912, at the request of the Commonwealth Government, he visited New Guinea for the purpose of investigating the possibility of the occurrence of oil in that country The results of his work there were embodied in a Memoir which was published by the Commonwealth Government. Both in the field and in the office, Mr. Carne was a tireless worker, and he never spared himself; his thoroughness in every branch of his work, even when he was getting on in years, was remarkable, and an object-lesson to all who came into contact with him. No country was too rough for him to traverse in carrying out his work, and nothing was ever taken for granted. So far as this Society was concerned, he took a very great interest in the work of the Geological Section, and was for several years its Chairman. As Government Geologist, he was a worthy successor to such men as W. B. Clarke and C. S. Wilkinson.

ALGERNON H. BELFIELD, who died on the 5th August last at the age of 83 years, had been a member of this Society for the past 46 years, having been elected in 1877. He was born in England but came to Australia while still a young man. He was one of the pioneers of the New England District, and spent the greater part of his life in the Armidale District, where he was a well-known and highly-respected pastoralist. He was an amateur astronomer of no mean order and had an observatory at his residence at Eversleigh Station, near Armidale.

WILLIAM GEORGE JIRA, who died on the 8th August last, had been a member of this Society for a few months only. He was a native of Bohemia, but arrived in Australia in 1895. He was a well-known figure in Sydney business circles, and carried on a large business as a gem merchant. He did a great deal to forward the Australian gem-stone industry, and was a well-known buyer on all our gem-fields.

CHARLES OSWALD HAMBLIN, B.SC., who died on 3rd October last, was one of our younger members, who was giving every promise of a useful scientific career and at the time of his death was one of the Honorary Secretaries of the Section of Agriculture. He was born in 1893, and was, therefore, only 29 years of age at the time of his death. He entered the services of the Department of Agriculture in Sydney in 1912, and in 1915 he enlisted with the A.I.F., and served four years abroad. On his return to Sydney in 1919 he resumed his departmental work, and was promoted to the position of assistant biologist, and still later to the position of principal assistant biologist, a position he held until his death. Mr. Hamblin rendered valuable service to the Department in connection with investigations of plant diseases, etc.

DUGALD THOMPSON, who died in November last, was one of our oldest members, having been elected a member in 1879. He was born in London, but came to Australia while still quite young. He was for many years a very prominent member of the business community in Sydney, and entered the political arena in 1894, when he became a member of the Legislative Assembly of New South Wales. In 1901 he was elected a member of the first Commonwealth Parliament, as the representative of North Sydney, and was Minister for Home Affairs in the Reid-McLean Ministry. In 1910, failing health caused him to retire from political life. He did not take any active part in scientific work, and did not often attend our meetings, but he nevertheless took a keen interest in scientific matters.

JAMES THOMAS WALKER, F.R.S.I., who died on 18th January last, was another of our older members, having been elected a member in 1899. He, also, was a well-known figure in Commonwealth political life, being a member for many years of the Commonwealth Senate. He was also a member of the National Convention which drafted the Commonwealth Constitution. Mr. Walker was a well-known figure in banking circles, and took an active part in philanthropic and educational movements.

ALBERT BOND, who died on the 27th March last, had been elected a member of our Society in 1878 and had thus been a member for 48 years. He was one of the oldest practising architects in Sydney, and for many years played a conspicuous part in the life of the Institute of Architects. He was responsible for designing a number of large city buildings. He would have been 81 years of age this month.

J. A. Pollock Memorial Fund.—A meeting of the many friends of our late honorary secretary was held in the Royal Society's House on the 21st June last, for the purpose of making arrangements to raise a fund to perpetuate his memory. At that meeting, a strong committee was formed, and as the result of their efforts the sum of £302 has been collected. The particular form which the memorial is to take has not yet been decided upon.

The National Research Council of Australia.—This Council, which is a branch of the International Research Council, held its second general meeting in Sydney in August last, when it completed the formation of its rules and transacted much other important business. The Executive reported that the Council had joined the International Unions of Astronomy, Geodesy and Geophysics, Pure and Applied Chemistry, Mathematics, and Radio-Telegraphy. The Executive also reported that arrangements had been made for the second Pan-Pacific Science Congress to be held in Australia in August, 1923, and that the Commonwealth Government had agreed to vote the sum of £5,000 for the expenses of the meeting. It was further reported that arrangements had been completed for the publication quarterly of Australian Science Abstracts, and that Part I. was available for issue. This publication must necessarily be of great use to Australian scientific workers.

The Forthcoming Pan-Pacific Science Congress.—The event of outstanding scientific importance this year will be the meeting of the second Pan-Pacific Science Congress in Australia in August next. The first Pan-Pacific Congress was held in Honolulu in September, 1920, under the auspices of the National Research Council of America and of the Pan-Pacific Union, and was in every way an unqualified success. At that meeting it was decided, if possible, to hold a similar conference every three years, the actual place of meeting being varied so that each important Pacific country might be visited in turn. The Honolulu meeting was attended by about 100 delegates from the United States, Canada, Philippine Islands, China, Australia, and New Zealand. It is confidently expected that a larger number of delegates will attend this next conference, and that all those countries which have interests in the Pacific Region will be represented. Intercourse with such a large gathering of eminent scientists from other lands must necessarily be of the greatest value to scientific workers in Australia; it will broaden their outlook and stimulate their research activities. At the Congress there will be discussed scientific problems, the solution of which will be of the very highest importance not only to Australia but to most of the nations around the Pacific. With its mandated territories, Australia has to face many new problems, and to hear the views of those who are faced with similar problems in other parts of the Pacific, must be of the highest value to all concerned. The Conference will have the further value of focussing the attention not only of scientists but also of Parliament and the public upon Pacific problems, and thus bring about a better realization of our duty to do our share towards solving these problems.

Australasian Association for the Advancement of Science.—This Association held its 15th meeting in January last in Wellington, New Zealand. The membership on this occasion numbered about 600; of these, about 450 enrolled in New Zealand, while about 150 enrolled in Australia. The number from Australia would have been larger but for the doubt which existed for some weeks before the meeting as to the certainty of getting both to and from New Zealand, owing to the maritime strike in New Zealand. As it happened, no great difficulty occurred.

The meeting was very successful from every point of view. Many valuable papers were read, and many important discussions took place. It would be of advantage, at least in some of the sections, if fewer papers of purely local interest were read, the time so saved being used for holding discussions on scientific problems of general Australasian importance. The subjects of these discussions should be selected beforehand, and members advised, so that they might prepare themselves for such discussions. This principle has been adopted for the forthcoming Pan-Pacific Congress, and if adopted as a regular thing by the Australasian Association, would add materially to the value of the meetings.

It was decided that the next meeting of the Australasian Association for the Advancement of Science would be held in Adelaide in September, 1924.

THE HISTORY OF VULCANISM IN NEW SOUTH WALES.

For the scientific portion of my address this evening, I purpose giving a summary of our present knowledge of past volcanic activity in New South Wales. The first summary on this subject was made by Prof. T. W. E. David(38) as far back as the year 1892, when, in his address to the geological section of the Australasian Association for the Advancement of Science, he gave a summary of the then knowledge of volcanic action in Eastern Australia. Nothing further in this direction for New South Wales was done until 1911, when the writer prepared a very brief summary for his book on the Geology of New South Wales.(66) A similar brief summary of New South Wales volcanic rocks was prepared for the State Handbook for the Meeting of the British Association in 1914.

Since 1892 very large additions to our knowledge of past volcanic action in this State have been made by various geological writers: the more important of these contributions are given in the list of references at the end of this address. Our knowledge of this subject for some few districts may now be said to be fairly complete; but for the State as a whole, our knowledge is still deplorably incomplete. Nevertheless, a summary of the existing knowledge should serve a useful purpose, not only as indicating what we do know, but also in drawing attention to the many gaps in our knowledge, and the large amount of research work still waiting to be done.

I. The Ordovician Period.

The earliest definite evidence we have of volcanic acticity in New South Wales occurs in Ordovician strata in the central part of the State. This area extends in an east and west direction from Newbridge to Parkes, northwards as far as Tomingly, and southwards as far as Carcoar; from many localities in this area andesitic lavas and tuffs have been recorded as occurring interstratified with strata of Ordovician age. E. C. Andrews(6) has recorded the occurrence of Andesitic lavas, breccias, and tuffs of supposed Ordovician age on the Parkes-Forbes goldfield, and a series of similar volcanic rocks from the Cargo goldfield.(8) J. B. Jaquet(47) has described the occurrence of augite-hornblende andesites at Carcoar, associated with claystones, shales, and argillaceous sandstones of supposed Ordovician age. The same writer has recorded the occurrence of very thick andesite flows at Cadia,(47) 15 miles from Carcoar. Here the andesites are associated with slates, tuffs, breccias, and beds of iron-ore of Ordovician age. The andesites at Cadia are highly altered, much of the augite being altered into uralite, and a considerable amount of chloritisation has taken place.

At Forest Reefs, not many miles from Cadia, the writer has noted the occurrence of massive andesite breccias, apparently interstratified with Ordovician strata. From Blayney, about 15 miles from Cadia, L. F. Harper (44) has described the occurrence of a thick series of andesitic lavas and tuffs, which he has doubtfully referred to the Silurian, but which may possibly be of Ordovician age. W. N. Benson (11) has recorded similar andesitic lavas of probable Ordovician age from Newbridge. E. F. Pittman (58) has recorded the occurrence of tuffs interstratified with Ordovician strata at Mandurama, on the Lyndhurst goldfield, but gives no information as to the composition of these tuffs.

While the actual geological horizon of some of the occurrences of volcanic rocks referred to above has not been absolutely determined, there can be no doubt that volcanic rocks, both lavas and tuffs, do occur in formations of Ordovician age at a number of places in this part of New South Wales, and that these rocks are for the most part andesitic in composition. Unfortunately, neither analyses nor detailed petrological descriptions of these rocks have been published. The Ordovician strata at all of the above localities are such as would have been deposited on a subsiding sea-floor far removed from any shore-line. These strata have a considerable thickness, but no measurements of their actual thickness have been made; also, the position of the volcanic rocks, whether high or low in the series, is still unknown. A more detailed knowledge of this Ordovician volcanicity is very desirable.

II. The Silurian Period.

Silurian volcanic rocks have been recorded from several localities in New South Wales, but speaking generally they are not common in formations of this age.

a. *Cobar-Canbelego District.*—E. C. Andrews(7) has described a thick bed of quartz-porphyry occurring in the Canbelego District, which he considers to be a lava flow of Silurian age, and to be a Rhyolite. He has traced this flow, with breaks, for a distance of 100 miles, and finds it to be associated with breccias and tuffs of similar acidic composition. Analyses of this flow are given in Table I.

b. *Orange District.*—The writer(64) has described rhyolite lavas and tuffs of Silurian age occurring at Gap Creek, in the Parish of Barton, County of Ashburnham. The rhyolite lava flow here is upwards of 200ft. thick, and is associated with tuffs which in turn are interstratified with mudstones and limestones of undoubted Silurian age. In some of the tuff beds there are ejected blocks of rhyolite ranging up to 8ft. in diameter. Not many miles from here, on the Cargo Goldfield, E. C. Andrews(8) found fine-grained tuffs interstratified with shales and limestones of Silurian age. From the same locality he also recorded a considerable thickness of andesites, trachytes, dolerites, and pitchstones, with associated breccias and tuffs, of doubtful age, but which he considered might be of Silurian age.

c. *Parkes-Forbes Goldfield.*—E. C. Andrews(8) has recorded the occurrence here of andesitic flows and tuffs, interstratified with sedimentary rocks of Silurian age.

d. *The Yass District.*—In 1911, A. J. Shearsby(61) described the occurrence of thick beds of quartz-porphyry interstratified with fossiliferous shales, limestones, tuffs, and breccias of Silurian age. He considered these to be contemporaneous rhyolite lava flows. The section at Yass is as follows:—

	Thickness.
The Hume Beds	2,000 Feet
The No. 3 Porphyry	650 „
The Yass Beds	1,200 „
The No. 2 Porphyry	1,500 „
The Bango Beds	800 „
The No. 1 Porphyry	1,200 „
The Jerrawa Shales	Unknown.

Shearsby described the No. 1 Porphyry as being clastic in places, and columnar in part. The No. 2 Porphyry he described as being coarsely spherulitic, and to have fossiliferous tuffs closely associated with it. He described the No. 3 Porphyry as resting upon coarse to fine tuffs, and to be overlain by well-bedded tuffs and breccias.

In a paper contributed to this Society in 1921, C. W. Mann(54) questioned Shearsby's determination with regard to beds Nos. 2 and 3, and concluded that they were intrusive into the Silurian strata. This conclusion has, however, not met with general acceptance; and it is still an open question as to who is right; but in any case, there are undoubted rhyolite tuffs and breccias interstratified with the Silurian strata.

The writer described in 1915(60) the occurrence of a quartz porphyry near the Jenolan Caves, which he thought might be a contemporaneous lava flow; but evidence now available shows this to be a sill.

Such information as is available, therefore, indicates that there was fairly widespread volcanic activity in the Silurian Period in New South Wales, and that the lavas and tuffs of this period are largely rhyolitic in character. Very little detailed investigation has, however, been carried out upon the volcanic rocks of this period. The eruptions took place in the sea, the lavas and tuffs being deposited upon a sea-floor which was fairly shallow, but which was undergoing a slow subsidence. The Silurian strata have a thickness of from 6,000 to 10,000 feet.

III. The Devonian Period.

The Devonian strata of New South Wales appear to have been deposited in two distinct provinces, under two quite different sets of conditions. This applies to the volcanic rocks as well as to the ordinary sediments. These two provinces have been described in some detail by Dr. W. N. Benson,(19) who has named them the Buchan-Murrumbidgee Province, and the Tamworth Province respectively.

A. *The South-Eastern or Murrumbidgee Province.*—This occurs in the south-eastern part of New South Wales. The strata occurring in it have been sub-divided as follows:—

c. The Upper Devonian or Lambian Series.
b. The Middle Devonian or Murrumbidgee Series.
a. The Lower Devonian or Volcanic Series.

Volcanic rocks occur in each of these sub-divisions.

a. *The Lower Devonian (Volcanic) Epoch.*—The rocks of this series are entirely volcanic in origin. They outcrop extensively in the valley of the Murrumbidgee River, south of the town of Yass. This occurrence has been described by L. F. Harper,(42) who states that the series ranges from 1,000 to 5,000 feet in thickness, and consists of rhyolite lava-flows and tuffs. The rhyolites contain phenocrysts of quartz, orthoclase, and oligoclase, set in a ground-mass which in many cases shows fluidal, spherulitic, and perlitic structures. The ground-mass is in most cases a devitrified glass, and usually there is considerable secondary silicification. The tuffs are of similar composition to the lava-flows.

There can be no question that the Murrumbidgee volcanic series is, as first suggested by A. J. Shearsby,(60) the equivalent in New South Wales, of the Snowy River Porphyries of Victoria. In both cases the eruptions appear to have taken place on a land surface, along an approximately meridianal line extending from the Yass District southwards to the Victorian border, and from thence southwards through Victoria, parallel to and just west of the Snowy River. It is unfortunate that so little detailed information is available regarding this interesting and important series of Lower Devonian volcanic rocks; there is here a very important petrological field awaiting investigation.

b. *The Middle Devonian or Murrumbidgean Epoch.*—Strata of this age, both in Victoria and New South Wales, occur in the same districts as the Lower Devonian volcanic series just described, and follow them quite conformably, the tuffs of the lower series merging upwards into the marine strata of the upper series. The Murrumbidgean series consists of coralline and brachiopodan limestones, tuffs, and tuffaceous shales of marine origin, and have, according to L. F. Harper,(42) an aggregate thickness of about 12,000 feet. He states that at least 8000 feet of this thickness consists either of tuffs or tuffaceous sediments. The tuffs are rhyolitic in character, consisting of fragments of rhyolite, felsite, quartz, and felspar. Two rhyolite flows, each about 400 feet in thickness, occur near the top of the series.

Tuffaceous rocks associated with marine sediments of Middle Devonian age have also been recorded by E. C. Andrews,(2) from Lobb's Hole, near Kiandra.

From the above facts, it would appear that at the close of the Lower Devonian Epoch, a subsidence began, which resulted in an extensive transgression of the sea over eastern Victoria and southern New South Wales, and that this subsidence was of such a magnitude as to allow of the accumulation of 12,000 feet of strata. The volcanic activity, which had been such a dominant feature of the Lower Devonian Epoch, still continued intermittently throughout the Middle Devonian Epoch, and was responsible for the deposition of enormous quantities of volcanic ash, which thus became interstratified with the Middle Devonian marine sediments. These two Epochs together constitute one of the great volcanic epochs of Australia.

c. *The Upper Devonian or Lambian Epoch.*—Important crustal movements appear to have taken place in south-eastern Australia at the close of the Middle Devonian Epoch. In Victoria the Upper Devonian freshwater strata rest upon the upturned edges of the Middle Devonian marine strata, with a marked unconformity. In southern New South Wales no contact between Middle and Upper Devonian strata has yet been recorded, but the existence of an unconformity between them is indicated by (a) the striking difference of the marine faunas of the two formations, and (b) the fact that whereas the Middle Devonian strata are very strongly folded and tilted, the Upper Devonian strata are for the most part much less folded and tilted. The Upper Devonian transgression extended over vast areas to the north and north-west of those reached by the Middle Devonian transgression.

It would appear, therefore, that folding and uplift affected southern New South Wales at the close of the Middle Devonian Epoch, followed however later by subsidence and transgression of the sea, for the most part in regions not previously covered by the Murrumbidgean transgression. This Upper Devonian transgression covered much of the south-eastern and central parts of New South Wales, and extended westwards past Bathurst, Orange, and Cobar, into the trans-Darling country, almost reaching the South Australian border in that direction. In this shallow, epicontinental sea was deposited a fairly thick series of conglomerates, sandstones, and mudstones, with, in some places, some limestones. In some localities volcanic rocks are associated with the marine sediments, but the volcanic activity appears to have been local rather than widespread.

From the Yalwal District, E. C. Andrews,(1) has recorded an alternating series of rhyolite and basalt flows, associated with the Upper Devonian strata which occur there. From the Upper Macquarie region, immediately to the west of the Blue Mountain tableland, L. F. Harper, (41), has recorded the occurrence of andesitic and rhyolitic lava flows and tuffs, associated with strata which he considers to be of Upper Devonian age, although he found no fossil evidence to actually prove this age.

Considerably further to the west, on the Canbelego Goldfield, E. C. Andrews,(7) noted the occurrence of tuffaceous sediments of Upper Devonian age. Neither analyses nor detailed petrological descriptions of any of these Upper Devonian volcanic rocks are available.

B. *The North-Eastern or Tamworth Province.*—This province occurs in the north-eastern part of the State. The Devonian strata in this region form a continuous outcrop extending around the southern and western margins of the present New England Tableland. Recent researches by Dr. H. C. Richards show that this belt extends into Southern Queensland. During the whole of the Devonian Period the sea which covered this area appears to have been very definitely isolated from those seas which covered other parts of New South Wales. In this region, also, volcanic activity was a very pronounced feature, and it constituted a very definite petrographical province, as the lavas and tuffs deposited over the whole of this area are of similar types. The volcanic rocks of this area are, however, quite different from those of the Murrumbidgee province, already described. They consist of spilites, dolerites, and keratophyres, with corresponding tuffs; and these are associated with a great development of radiolarian rocks. This series of volcanic rocks has been very fully investigated by Dr. W. N. Benson, (11) and the following facts and the accompanying rock analyses are taken mainly from his published descriptions.

Dr. Benson has sub-divided the Devonian strata of the Tamworth province as follows—

1. Upper Devonian—The Barraba Series.
2. Middle Devonian—The Tamworth Series.
3. Lower Devonian—The Woolamin Series.

These strata, which were deposited under marine conditions, have a thickness of from 15,000 to 20,000 feet, and a very considerable proportion of this thickness is made up of volcanic rocks (lavas, tuffs, and breccias). The volcanic rocks from a remarkable series of spilites, dolerites, and keratophyres. Some of the spilites, and all of the dolerites and keratophyres have intrusive relations with the associated marine sediments; but it is considered that they were intruded during the Devonian Period into the still more or less unconsolidated marine sediments not far below the actual sea bottom; and as, moreover, extensive depositions of volcanic fragmental material of similar mineral and chemical compositions to the lavas took place at the same time on the sea bottom, the whole series is looked upon as a contemporaneous volcanic series. Volcanic activity was strongly marked throughout the Lower Devonian Epoch, the lavas and tuffs being predominantly spilitic and doleritic. During the Middle Devonian Epoch, volcanic activity was still very pronounced, but here the keratophyres assumed a greater relative importance. In the Upper Devonian Epoch, the volcanic activity waned considerably, but keratophyre tuffs were deposited extensively on the sea bottom.

(a.) *The Spilites.*—These are strongly developed both in the Woolamin and Tamworth Series, the individual beds ranging up to 400 feet in thickness. At Bundook, a few miles north of the town of Gloucester, there is an occurrence of spilites from 2000 to 3000 feet in thickness. Whether this occurrence is intrusive or is an actual flow or series of flows is not known. The predominant mineral in the spilites is an acid plagioclase (albite or acid oligoclase); augite occurs in amounts varying from one-fifth to one-half that of the felspar. Ilmenite or titaniferous magnetite occurs in small but varying properties, and there is a little apatite present. In some few cases a little quartz is also present. Reference to the chemical analyses in Table I. shows that the chief chemical feature is the richness in soda, and the low alumina, potash, and lime. Some examples of this rock are porphyritic; vesicular and amygdaloidal structures also occur. Pillow-structure is commonly present.

(b.) *The Dolerites.*—These are always intrusive, but are considered to belong to the volcanic series. They differ from the spilites mainly in their coarser grain-size, their microscopic structure, and the absence of pillow-structures. Chemically, as may be seen from the analyses in Table I., they are practically the same. In some examples, sufficient quartz occurs to give quartz-dolerites.

(c) *The Keratophyres.*—These and their tuffs are moderately abundant in the Woolamin Series, but have their greatest development in the Tamworth Beds. The normal keratophyres consist almost entirely of acid plagioclase, with a little magnetite, and more rarely a little augite. They grade, on the one hand, by increase of magnetite, into magnetite-keratophyres, and, on the other hand, with appearance of quartz, into the quartz-keratophyres; the magnetite-keratophyres, again, by increase of augite, grade into the spillites. The massive keratophyres occur mainly as intrusive sills, but tuffs and breccias of similar mineral and chemical composition are abundantly developed. By reference to the analyses, it will be seen that the keratophyres, like the spilites, are rich in soda, and poor in potash.

(d) *The Tuffs and Breccias.*—Fragmental material, analogous in mineral and chemical composition to the spilites, dolerites, and keratophyres, are abundantly developed throughout the series, varying from fine tuffs to coarse breccias. An interesting feature of the keratophyric tuffs is their intrusive relations in many places with the enclosing sediments. This interesting feature was first pointed out by Messrs. David and Pittman, and was later fully described and the cause discussed by Dr. W. N. Benson, (14). One very striking occurrence of fragmental rock in this series is the Baldwin agglomerate, which occurs just on the dividing line between the Tamworth Series with the overlying Barraba Series. This bed, which ranges up to 2000 feet in thickness, consists of rounded boulders of granite, quartz-porphyre, keratophyre, spilite, andesite, augite-porphyrite, dolerite, radiolarian chert, and cherty tuffs set in a tuffaceous matrix of andesitic composition. An analysis of this matrix is given in Table I.

IV. The Carboniferous Period.

The Carboniferous Period, so far as the north-eastern part of the State is concerned, was one of the greatest periods of volcanic activity that New South Wales has seen. A thickness of nearly 20,000 feet of strata was deposited during the period, and of this thickness a very considerable proportion consists of volcanic material. The Carboniferous System in New South Wales is divided into two series, viz.: (a) The Burindi Series, deposited under marine conditions; and (b) The Kuttung Series, deposited under terrestrial conditions.

A. The Burindi Epoch.

The Burindi sedimentation took place in a shallow sea, the floor of which was undergoing subsidence. The only complete section of these strata, yet published, occurs in the Gloucester District.(67)

TABLE I.—ANALYSES.

HORIZON.	ROCK-NAME.	LOCALITY.	SiO_2	Al_2O_3
Silurian	Rhyolite	Canbelago District	73·33	12·43
do.	do.	do.	77·39	9·50
Middle Devonian	Spillite	Nemingha	50·17	15·56
do.	do.	Nundle	48·22	14·82
do.	Dolerite	do.	48·35	14·12
do.	Quartz Dolerite	Hanging Rock	54·88	12·62
do.	Matrix of Agglom'ate	Tamworth	52·88	21·25
do.	Tuff	do.	56·06	18·36
do.	Magnetite Keratophyre	Hydes' Creek	56·95	17·87
do.	Keratophyre	Nundle	60·39	18·40
do.	Quartz Keratophyre	Nemingha	71·52	11·76
Burindi Series	do.	Gloucester District	69·82	12·41
do.	do.	do.	74·56	12·87
Kuttung Series	Andesite	Pokolbin	55·20	20·14
do.	Andesite Pitchstone	do.	58·79	17·51
do.	do.	Currabubula	60·26	16·46
do:	Quartz Andesite	Martin's Creek	64·20	16·88
do.	Rhyolite	Gloucester District	77·76	9·94
do.	do.	Mount Bright, Polkolbin	77·82	11·46
do.	do.	Paddys Hill, Raymond Terrace	75·06	14·21
do.	Soda Rhyolite	Bulladelah	71·35	12·80
Permo-Carboniferous				
Upper Marine Series	Basalt	Blow Hole Flow, Kiama District	51·92	15·58
do.	Latite	Bimbo Flow, do.	55·19	16·18
do.	do.	Saddleback Flow, do.	52·48	17·32
do.	do.	Cambewarra Flow, do.	58·82	14·78
Upper Coal Measures	do.	Minnamurra Flow, do.	51·32	18·82

TABLE II.—ANALYSES.

HORIZON.	ROCK-NAME.	LOCALITY.	SiO_2	Al_2O_3
Tertiary Period.				
Monadnock Basalts	Olivine Basalt	Mount Tomah, Blue Mountains	46·42	17·42
do.	do.	Bald Hills, Bathurst	44·67	21·38
Plateau Basalts	Dolerite	Midderula (? flow)	45·25	15·13
do.	Neph. Basalt	Mount Molong, Blue Mountains	49·82	17·53
do.	Olivine Basalt	Orange	48·92	14·87
do.	do.	Hill End	44·66	13·37
do.	do.	Bowral	43·31	16·68
do.	do.	Robertson	44·57	15·30
do.	Neph. Basanite	Square Top, Nundle	47·56	15·20
do.	Corundum Basalt	Billy Kings Crk., Connabarabran	48·27	18·02
do. (?)	Basalt	Mount Lindsay (3000 ft.)	47·50	14·19
Alkaline Series	Trachyte	Mount Jellore near Mittagong	66·68	14·53
do.	Comendite	Warrumbungle Mountains	74·12	12·39
do.	Arfvedsonite Trachyte	do.	65·90	16·74
do.	Soda Trachyte	do.	60·73	18·16
do.	Nosean Phonolite	do.	60·32	18·32
do.	Trachy-Andesite	do.	58·95	17·04
do.	Orthoclase Basalt	do.	51·88	14·20
do.	Trachyte	Nandewar Mountains	64·63	16·55
do.	Phonolite	do.	61·27	16·00
do.	Phonolitic Trachyte	do.	51·98	22·46
do.	Comendite	Canobolas Mountains	72·06	13·86
do.	do.	do.	69·28	14·58
do.	Phonolitic Trachyte	do.	57·39	16·88
do.	Porph. Olivine Basalt	do.	49·26	18.56
do.	Pitchstone	Mount Lindsay, McPherson Rg.	73·35	10·96
do.	do.	McPherson Range	71·98	12·02
do.	Rhyolite	Springbrook Plat., McPher. Rg.	78·10	13·09
do.	Andesite	do.	54·10	18·42
do.	Lencite Basalt	Lake Cudgellico	44·68	11·43

Palæozoic Volcanic Rocks.

Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O+	H_2O-	CO_2	TiO_2	P_2O_5	ANALYST.
0·10	2·43	0·59	0·98	2·71	5·66	1·41	0·09	trace	0·23	0·11	H. P. White
0·30	1:08	0·17	0·42	1·72	6·54	2·14	0·08	trace	0·45	0·06	do.
2·18	12·06	3·49	7·77	4·12	0·38	1·12	0·27	0·21	1·51	0·18	W. N. Benson
0·56	9·25	5·58	8·81	4·95	0·44	2·54	0·15	1·40	2·68	0·23	do.
4·87	10·27	4·78	6·71	4·63	0·38	2·00	0·30	...	2·84	0·35	do.
3·02	7·11	3·73	4·16	6·01	1·10	1·76	0·23	...	3·63	0·44	do.
2·73	8·02	4·93	7·40	3·95	1·15	2·53	0·25	0·20	...	0·29	do.
4·40	2·68	4·58	6·06	3·71	0·66	2·50	0·28	0·24	...	0·19	do.
4·49	6·00	0·93	2·30	8·80	0·38	0·71	0·38	0·91	0·89	trace	do.
1·03	3·50	1·27	1·53	8·79	0·46	1·37	0·20	1·70	0·80	0·12	do.
1·52	3·44	1·18	2·72	5·05	0·26	1·25	0·14	0·38	0·28	0·20	do.
1·10	0·54	0·29	1·86	4·63	1·67	1·05	6·55	0·03	0·25	0·03	W. G. Stone
1·80	0·36	0·29	0·28	4·91	3·43	0·91	0·35	0·01	0·40	0·04	do.
3·55	3·46	1·10	9·17	4·80	0·96	1·25	0·10	...	1·17	trace	W. R. Browne
2·11	3·87	2·23	6·18	4·84	0·68	2·61	0·71	trace	1·21	...	do.
1·15	4·87	3·09	5·25	4·23	0·98	2·22	0·22	...	0·84	0·29	W. N. Benson
1·90	2·52	0·66	3·14	4·41	3·52	1·79	0·31	0·03	0·65	0·13	W. G. Stone
1·15	0·59	0·18	0·24	0·86	7·75	1·00	0·38	0·03	0·15	0·03	do.
0·30	0·09	0·23	0·22	0·86	7·19	1·40	0·36	0·03	0·02	0·04	J. C. H. Mingaye
1·31	0·27	0·09	0·42	6·88	0·58	0·62	0·57	...	...	0·03	W. G. Greig
0·80	0·36	0·13	0·68	2·24	3·54	1·87	6·54	...	...	...	do.
5·00	4·68	4·09	7·72	3·38	2·56	1·35	1·19	0·02	1·20	0·54	J. C. H. Mingaye
3·52	3·94	3·04	4·68	5·09	4·10	1·75	0·99	0·28	0·89	0·59	H. P. White
4·30	5·04	3·65	7·66	3·43	2·53	1·61	0·59	0·17	0·74	0·42	do.
3·90	3·24	2·26	3·09	4·67	4·70	1·36	0·81	0·05	1·78	0·58	J. C. H. Mingaye
4·50	2·97	2·58	6·42	3·97	3·31	2·89	0·87	0·10	0·56	0·42	H. P. White

Tertiary Volcanic Rocks.

Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O+	H_2O-	CO_2	TiO_2	P_2O_5	ANALYST.
3·70	7·45	6·61	8·56	3·61	1·80	0·34	1·52	0·04	1·88	0·87	J. C. H. Mingaye
2·82	5·99	9·58	10·24	2·70	1·03	0·79		...	trace	0·22	do.
1·80	8·82	10·24	10·98	3·36	1·22	0·09	1·21	0·06	1·52	0·52	H. P. White
4·30	7·11	3·02	5·26	5·90	2·35	0·30	1·31	0·04	2·01	0·88	do.
3·99	7·44	5·73	7·26	3·42	1·80	0·82	1·56	0·09	2·78	0·59	J. C. H. Mingaye
2·10	8·01	13·84	8·88	3·15	2·16	0·23	1·75	..	1·60	0·37	H. P. White
2·31	9·00	10·56	7·95	2·94	0·97	0·88	1·72	0·03	2·20	0·65	D. Mawson
3·20	7·83	10·04	10·00	1·94	1·39	1·09	3·21	0·01	1·01	0·41	H. P. White
4·75	6·12	5·44	6·15	6·40	2·32	2·20	0·26	absent	2·40	0·56	W. N. Benson
12·06	...	1·17	6·06	3·73	3·33	0·52	0·85	0 30	4·87	trace	H. I. Jensen
1·78	12·15	5·06	7·47	3·85	1·58	1·59	0·33	...	3·08	0·79	G. R. Patten
2·18	2·31	0·30	1·88	6·12	4·02	0·38	0·83	0·05	0·20	0·28	D. Mawson
0·31	0·21	0·42	0·30	3·22	5·07	2·10	2·22	...	...	...	J. C. H. Mingaye
1·72	1·99	0·06	0·09	6·35	5·77	0·43	0·27	absent	0·25	absent	H. I. Jensen
4·63	0·20	0·31	0·10	4·88	6·21	1·33	0·72	trace	0·60	absent	do.
3·55	1·96	0·01	1·12	7·01	6·25	1·31	0·88	trace	0·25	absent	do.
2·80	4·66	0·57	2·49	4·51	6·39	1·28	0·59	0·06	0·76	trace	do.
3·72	6·87	4·62	6·36	3·93	3·27	1·44	0·58	0·29	3·54	trace	do.
2·98	1·16	0·16	0·46	5·23	6·11	1·35	1·05	trace	0·58	absent	do.
2·59	4·04	0·39	1·93	4·25	6·31	0·36	0·64	0·16	1·02	...	do.
2·48	1·87	0·83	4·63	3·66	3·93	2·06	1·08	0·04	4·71	...	do.
1·90	1·71	0·19	0·18	5·84	3·69	0·33	0·21	0·03	0·12	0·16	H. P. White
2·54	0·67	0·30	0·44	6·82	3·95	0·94		...	0·13	...	H. I Jensen
1·09	6·10	1·01	3·16	6·71	5·86	0·49	0·11	...	1·11	...	do.
3·80	6·12	3·71	7·40	3·61	2·21	0·95	1·64	0·20	1·85	0·78	W. G. Stone
2·60	1·50	0·17	1·03	3·26	4·87	3·50	0·35	...	nil	0·09	J. C. H. Mingaye
1·20	1·08	0·16	0·64	3·04	5·07	3·86	1·02	0·01	0·13	0·02	do.
1·19	1·43	0·43	0·87	4·03	4·93	0·54	nil	...	0·39	0·11	G. R. Patten
4·06	7·43	4·43	7·97	3·81	1·15	0·88	nil	...	2·35	0·46	do.
7·00	4·67	10·25	9·44	1·56	5·68	0·77	2·73	0·20	0·84	0·66	W. A. Greig

(a) *The Gloucester District.*—The Burindi series here is about 10,000 feet in thickness, and consists of conglomerates, mudstones, limestones, tuffs, and lava flows. Throughout the whole series, beds of tuffs occur interstratified with the other sediments, and many of these sediments are tuffaceous. These tuffs appear, for the most part, to be keratophyre tuffs. The volcanic material is most strongly in evidence in the upper half of the series, and here there are three lava flows with an aggregate thickness ranging up to nearly 1000 feet. These lavas, as will be seen from the analysis on Table I., have the composition of quartz-keratophyres; they consist very largely of quartz and felspar, and contain a very high proportion of albite felspar, and with little or no ferro-magnesian minerals.

(b) *The Clarence Town District.*—A similar series of Burindi Beds occur here, but only the upper portion is exposed. Tuffs similar to those of the Gloucester District are abundantly developed, and here also there are three lava flows. In a previous communication by the writer, (68) they have been referred to as andesite, but as they are highly aphanitic, and as no analyses were made, it may possibly be that they also are keratophyres.

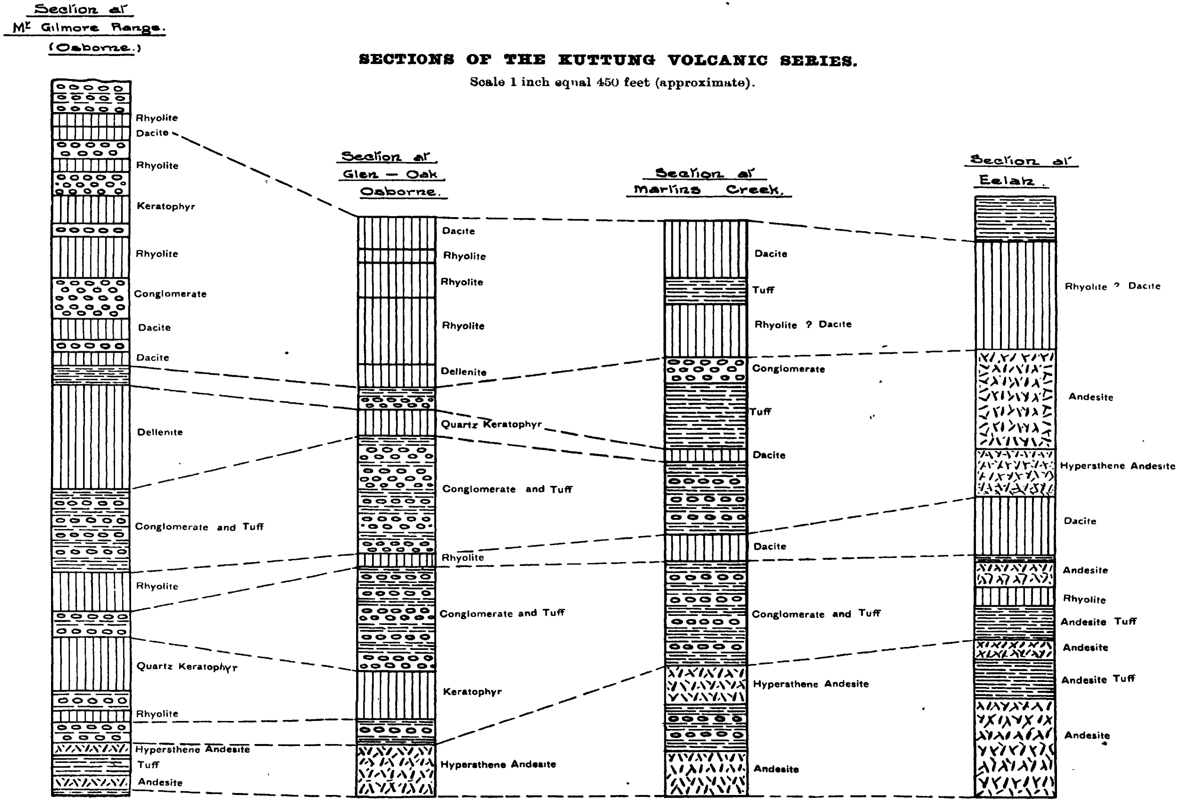
(c) *The Currabubula District.*—W. N. Benson, (16) has described the occurrence of tuffs in the Burindi Beds here, but has not recorded any lava flows.

B. The Kuttung Epoch.

It was during this epoch that the culmination of the volcanic activity of the Carboniferous Period took place. That part of the State which had been under marine conditions during the Burindi Epoch, now become dry land. and on this land centres of volcanic activity developed. from which immense quantities of lava and volcanic ash were ejected. In the southern part of the area, a continu-

SECTIONS OF THE KUTTUNG VOLCANIC SERIES.

Scale 1 inch equal 450 feet (approximate).


Section at Mt Gilmore Range. (Osborne.)
Rhyolite
Dacite
Rhyolite
Keratophyr
Rhyolite
Conglomerate
Dacite
Dacite
Dellenite
Conglomerate and Tuff
Rhyolite
Quartz Keratophyr
Rhyolite
Hypersthene Andesite
Tuff
Andesite
Section at Glen – Oak Osborne.
Dacite
Rhyolite
Rhyolite
Rhyolite
Dellenite
Quartz Keratophyr
Conglomerate and Tuff
Rhyolite
Conglomerate and Tuff
Keratophyr
Hypersthene Andesite
Section at Martins Creek.
Dacite
Tuff
Rhyolite ? Dacite
Conglomerate
Tuff
Dacite
Dacite
Conglomerate and Tuff
Hypersthene Andesite
Andesite
Section at Eelah.
Rhyolite ? Dacite
Andesite
Hypersthene Andesite
Dacite
Andesite
Rhyolite
Andesite Tuff
Andesite
Andesite Tuff
Andesite

ous line of volcanic rocks extends from Port Stephens on the coast westwards past Clarence Town, Seaham, Paterson, Eelah, and Hudson's Peak, to Muswellbrook, and swings northwards from there to Scone and Currabubula, a distance of about 150 miles. Northwards of the Hunter River are volcanic rocks of similar age, which have been recorded at Stroud Road, Gloucester, and on the Drake Goldfield. These volcanic rocks have been studied in some detail in the Hunter River District, where the Kuttung Series has been sub-divided as follows (in descending order:—

		Maximum Thickness, Feet.
III.—The Glacial Stage ..	The Main Glacial Beds.. ..	1840
	The Paterson Toocanites ..	290
	The Mt. Johnston Beds . ..	2100
II.—The Volcanic Stage	The Mt. Gilmore-Martin's Creek Beds	2600
I.—The Basal Stage	The Wallarobba Tuffs	800
	The Wallarobba Conglomerates	1500
	Total	9130

Volcanic rocks occur to a greater or less extent throughout the whole series, but attain their maximum development in the middle or volcanic stage.

(a) *The Seaham-Paterson Area* (Lower Hunter River Area).—The Wallarobba conglomerates have a more or less tuffaceous matrix, and contain layers of tuffs intertratified with them. The Wallarobba tuffs, which follow them, have not been examined petrologically, but are either andesitic or keratophyre tuffs. With regard to the volcanic stage, the succession of strata is given for four localities in Plate I. This stage has its greatest thickness in the Mt. Gilmore Range, near Clarence Town, where the thickness is 2900 feet, and includes 13 distinct lava flows, with an aggregate thickness of 1,375 feet.(57) Tuffs and tuffaceous conglomerates are inter-bedded with these flows. The sections at Glen Oak and Martin's Creek are in general similar to that at the Mt. Gilmore Range, but the section at Eelah is somewhat different, consisting very largely of lava flows only, and these include a much larger proportion of andesites than occur elsewhere, aggregating nearly 1000 feet in thickness. In the succeeding glacial stage there is a considerable development of tuffs in the Mt. Johnstone Beds, followed by a final lava flow, the Paterson Toscanite, ranging up to 290 feet in thickness, while the succeeding Main Glacial Beds also contain some tuffs.

The order of succession of the lava flows from the Kuttung Series is generally as follows:—

1. Hornblende Andesite.
2. Hypersthene Andesite Glass.
3. Quartz Keratophyre.
4. Rhyolites, Dacites, and Dellenites.
5. Toscanite.

And if we consider the volcanic activity as continuing on into the Lower Marine sub-division of the Permo-Carboniferous System, we get a final eruption of basalts, which occurs not far above the top of the Kuttung Series.

The succession at Eelah, as may be seen by Plate I., was somewhat different. There are also differences in the section described by Messrs. Browne and Walkom,(23) at Pokolbin, some miles south of Eelah, who give the following succession for that locality:—

1. Rhyolite.
2. Trachyte (? Keratophyre).
3. Trachyte-Andesites.
4. Dacites.

These differences are probably due to overlapping of lava flows from different centres of eruption. The great thickness of andesites at Eelah suggests that the andesites came mainly from that neighbourhood. Prof. T. W. E. David, (39) has described a great mass of andesite occurring at Blair Duguid, some eight miles to the south-west of Eelah. This mass of andesite is now surrounded by the Lower Marine Series of Permo-Carboniferous age, and was at one time completely submerged by them. It no doubt stood as an andesitic volcano on the Kuttung land-surface, and as this land subsided in the succeeding Lower Marine Epoch, it became an island, and was finally submerged under the Lower Marine Sediments; these latter, in the neighbourhood, contain conglomerates composed largely of andesite boulders. Eastwards, the andesites become progressively thinner; at Martin's Creek they are 350 feet in thickness, while at the Mt. Gilmore Range they are only about 100 feet in thickness. In the Mt. Gilmore Range, on the other hand, the more acid lavas have their greatest thickness, and there was no doubt a centre of eruption somewhere hereabouts. At Paddy's Hill, some three miles east of Mt. Gilmore, there is a rhyolite hill surrounded by the Lower Marine natrolite basalts. This, also, was a Kuttung volcano, later surrounded by the Permo-Carboniferous sea, and subsequently covered by Permo-Carboniferous sediments, and, like Blair Duguid, now again re-exposed to view by recent denudation.

A number of analyses of Kuttung lavas are given in Table I., but no complete set of analyses of all the flows from any one locality has yet been made, and until this is done it will be difficult to correlate the flows from different localities, as the names now given to some of these flows may need revision when more complete chemical data are available. Dr. W. R. Browne is now engaged in making a detailed study of the Kuttung lavas of the Hudson's Peak area, while Mr. G. Osborne is doing similar work from the Paterson-Seaham area. Their results will be awaited with much interest.

(b) *Muswellbrook and Scone.*—At both of these localities, the writer has noted the occurrence of acidic and sub-acidic lava flows interstratified with the Kuttung sediments, which lie just east of these two towns. These lava flows are exactly like those of the Seaham-Paterson area.

(c) *Currabubula.*—Messrs. Benson and Browne, (20) have described the Kuttung series of this area, and have recorded the occurrence of a considerable development of keratophyre tuffs, but no corresponding lava flows. They have also noted the occurrence of sills of andesite intruding the Kuttung series; both chemically and mineralogically these are similar to the andesite lava flows of the Lower Hunter, and are considered to belong to the same series. These sills range up to 1500 feet in thickness; analyses of them are given in Table I. An interesting feature here is the occurrence of several small flows of basalt and some basalt tuffs in the upper part of the Kuttung series. Dr. Benson has also noted the occurrence of some dacitic lava flows still further north, at Nundle.

(d) *Gloucester District.*—The Burindi Series of this district has already been referred to on page 23. The Kuttung Series, which overlies the Burindi Series here, consists almost entirely of rhyolite lava flows, aggregating 1500 feet in thickness. No andesites appear to occur here. These rhyolites form the backbone of the ranges which occur both to the east of the town (Mograni Mountain), and to the west of the town (Gloucester Buckets). From the analysis given in Table I., it will be seen that the lava here is a typical potash rhyolite.

(e) *Drake District.*—In 1908 E. C. Andrews, (5) described a series of volcanic rocks occurring in the Drake Goldfield, which he considered represents two periods of volcanic activity, as follows:—

(1) An older one, productive of whitish to grey felsites, purple and green lavas, tuffs and breccias.

(2) A younger one, productive of blue and purple agglomerates, breccias, lavas, and tuffs, associated with marine sediments.

He included both of these in the Permo-Carboniferous system, but is now of opinion that the lower series is probably of Kuttung age.

The older or Kuttung Series consists of rhyolites and rhyolite breccias and tuffs, traversed by numerous quartz veins. Mt. Carrington, near Drake, is considered by Mr. Andrews to be a much-dismembered volcanic pile, later submerged and covered by the Lower Marine rocks.

V.—The Permo-Carboniferous Period.

Volcanic activity, which had been such a pronounced feature during the Carboniferous Period, still continued, during the succeeding Permo-Carboniferous Period, but with much less intensity, and at no one locality did it continue throughout the period, The subdivisions of the Permo-Carboniferous Period with the volcanic activity is shown in the following table in descending order:—

Epochs.	Localities where Volcanic Rocks occur.	Nature of the Volcanic Rocks.
Upper Coal Measures	Murrurundi Dist.	Basalts.
	Illawarra Dist.	do.
	Lithgow and Newcastle Dists.	Acidic Tuffs (Cherts).
Dempsey Shales	None.	None.
Middle Coal Measures	do.	do.
Upper Marine Series	Illawarra Dist.	Basalts & Latites.
Lower Coal Measures	None.	None.
Lower Marine Series	Hunter River Dist.	Basalts.
	Drake Dist.	Basic and Intermediate Tuffs and Breccias.

It will be seen from the above that most of the volcanic rocks belonging to this period are basalts and latites.

(a) *The Lower Marine Epoch.*—In the Hunter River District(29) there occurs near the base of the Lower Marine Series a thick and persistent bed of basalt. In the neighbourhood of Raymond Terrace this flow (or series of flows) attains a thickness of about 1200 feet, and has tuffs and tuffaceous shales both above and below it. It extends from here westwards to Gosforth and Pokolbin, but with decreasing thickness, but still forms a prominent horizon in the Lower Marine Series. No analysis of this basalt is available, but Dr. W. R. Browne reports that the basic felspars in this rock at Gosforth are sodic, showing both albitization and scoletization, and concludes that the rock has affinities with the spilites. No pillow structure has yet, however, been recorded. Probably belonging to this horizon is a series of basalts and basalt tuffs and agglomerates, occurring at Warragundi Mountain, near Currabubula. Messrs. W. N. Benson and W. R. Browne,(20) have described this occurrence, and suggest that Warragundi Mountain was a centre of eruption.

As this basalt horizon occurs not very far above the top of the Kuttung Series, it is quite possible that this flow is really a continuation of the Kuttung volcanic series already described, and was the closing phase of that period of vulcanicity.

From the Drake District E. C. Andrews,(5) has described the occurrence of a series of andesitic breccias and tuffs and lavas, interstratified with strata containing marine fossils, and occurring at the base of the Lower Marine Series. These, also, follow closely upon the Kuttung volcanic series of that district, as described in the previous section.

No other volcanic horizon has been recorded from the Lower Marine Series, nor have any volcanic rocks been recorded from the Lower Coal Measures.

(b) *The Upper Marine Epoch.*—Although the Upper Marine Series have a thickness of about 6000 feet in the Hunter River District, they contain no volcanic rocks, but during this epoch a centre of vulcanicity developed in what we now call the Illawarra District. The upper part of the Upper Marine Series, in parts of the district, consist practically entirely of volcanic rocks, aggregating 1200 feet in thickness, and the volcanic rocks extend into the lower part of the Upper Coal Measures. These volcanic rocks have their maximum development in that part of the district adjacent to the town of Kiama, and the succession of rocks here is shown in descending order in the following table compiled by Mr. J. B. Jacquet (26) :—

		Thickness, Feet.
Upper Coal Measures ..	Shales and Coal Seams ..	140-530
	Minnamurra Flow	120
	Tuffs	30
Upper Marine Series ..	Cambewarra Flow	60-600
	Saddleback-Dapto Flow ..	100-250
	Jamberoo Tuffs	180-510
	Bumbo Flow	30-500
	Kiama Tuffs	120
	Blowhole Flow	140
	Westley Park Tuffs	40
	Marine Strata .. .. .. ab.	2000

These volcanic rocks extend as far north as Wollongong, and as far south as Termeil, a total length of 52 miles. Most of the flows appear to thicken eastwards and to thin out westwards, indicating that the points of eruption were probably eastwards of the present shore-line. Mr. L. F. Harper (40a) considers that there were at least three distinct centres of eruption—one at the southern end near Termeil, one in the neighbourhood of Kiama, and one near Port Kembla.

Analyses of these flows are given on Table I., and it will be seen that for such basic rocks they are rather rich in alkalies, particularly potash; and the normative mineral composition of these lavas gives from 15 to 34 per cent.

of orthoclase molecules. Dr. W. R. Browne has pointed out that some of these rocks show evidence of albitization; they should, therefore, be classed with the latites rather than with the basalts. The petrology of this series has been fully described by Mr. G. W. Card.(26)

No volcanic rocks appear to occur in the Middle Coal Measures, nor in the Dempsey Beds.

(c) *Upper Coal Measures.*—The occurrence of basalts (latites) and tuffs in the Upper Coal Measures of the Southern Illawarra District has already been referred to. Basalts occur also in this series in the north-western coal basin at Murrurundi and at Gunnedah. From Murrurundi, Mr. J. E. Carne,(29) recorded the occurrence of basic lavas and tuffs 1200 feet in thickness, associated with the Upper Coal Measures. No detailed description of these volcanic rocks has, however, been published.

An interesting feature of the Upper Coal Measures is the occurrence of a number of beds of chert which have apparently a volcanic origin. These beds are well-developed in the neighbourhood of Newcastle, and also occur in the Lithgow District; the beds range from a few inches up to several feet in thickness, and are regularly interstratified with the other rocks of the coal-measures. Mr. G. W. Card, who has examined these cherts under the microscope, states that they consist of minute fragments of felspar and volcanic glass. This material is exceedingly fine, and may have come a very long distance; all that can be said is that during the Upper Coal Measure Epoch showers of the very finest volcanic ash fell at intervals into the coal-measure swamps, derived probably from some quite distant source.

VI. The Mesozoic Era.

Volcanic action, which had been so prevalent in New South Wales during the Paleozoic Era, appears to have been almost entirely absent during the Mesozoic Era. The exception is the occurence of some tuffaceous beds in the Narrabeen Series, the lowest subdivision of the Triassic System. Two horizons of these tuffs occur—(a) The tuffaceous beds which occur about 500 to 600 feet above the base of the Narrabeen beds; and (b) the Chocolate Shales which occur near the top of the Narrabeen Beds.

(a) *The Tuffaceous Sandstones.*—These have been observed mainly in boreholes, and the analysis quoted below is from a sample obtained from a borehole at Rose Bay, Sydney, about 1900 feet below the surface. The analysis indicates the tuffaceous nature of these beds. They are commonly slightly cupriferous.

(b) *The Chocolate Shales.*—These form a characteristic and well-marked horizon near the top of the Narrabeen Beds, and occur throughout the Hawkesbury Basin. They have a deep chocolate-red colour, are very fine-grained, show but little lamination, and are regularly interstratified with fresh-water shales and sandstones. Their peculiar lithological characters are persistent throughout the whole area, and this makes them a very useful horizon for field-mapping. The two analyses given below, from localities nearly 40 miles apart, show also the persistent chemical composition. These chocolate shales are considered to be re-distributed tuffs, although the chemical composition is not very strongly suggestive of a volcanic origin.

	Analyses of Chocolate Shale.		**Tuffaceous Sandstones.**
	Helensburgh.	**Long Reef. Narrabeen.**	**Rose Bay Bore, Sydney (Depth, 1900ft.).**
SiO_2	36.42	38.98	61.65
Al_2O_3	31.48	28.00	13.29
Fe_2O_3	15.50	14.39	2.94
FeO	0.45	0.98	6.44
MgO	0.36	0.36	3.44
CaO	0.60	0.15	1.64
Na_2O	0.24	0.08	2.44
K_2O	0.09	0.18	0.66

	Helensburgh.	Long Reef, Narrabeen.	Rose Bay Bore, Sydney. (Depth 1900 ft)
H_2O	1.77	3.60	1.30
H_2O+	10.19	10.38	4.02
CO_2	—	0.22	0.90
NO_2	2.24	2.05	0.97
P_2O_5 ..	0.12	(?)1.06	0.05
CuO	—	0.11	0.01

Analysts—E. G. Walton and E. S. Bonney, B.A.

VII. The Cainozoic Era.

Volcanic rocks of Tertiary age occur extensively in the eastern tableland belt of New South Wales. These volcanic rocks, according to the writer's views, belong to at least three separate geological epochs, as follows:—

Classification of the Tertiary Volcanic Rocks.

Late Tertiary—The Alkaline Series	The Leucite Basalts. Sub-Alkaline and Normal Basalts. Phonolites and Trachy-Andesites. Alkaline Trachytes. Rhyolites, Comendites, and Pantelarites.
Upper Miocene or Lower Pliocene—The Plateau Basalts	Basalts resting upon the surface of the East-Australian peneplain.
Lower Tertiary (Up. Cretaceous)—The Monadnock Basalts	Basalts capping residuals of the Cretaceous Peneplain.

It should be understood that the above classification has not yet received general acceptance. Some previous writers, for example, were of the opinion that the Alkaline Series were of Eocene age, and older than the plateau basalts.

In arriving at the above opinions as to the relative ages of the various Tertiary volcanic rocks, the writer has been guided to a considerable extent by physiographical evidence, as the palaeontological evidence is both limited and indefinite.

In Fig. 1, is given a section of Mt. Dangar and the adjoining portion of the Merriwa Tableland. The latter has here a general altitude of about 1400 feet, and is

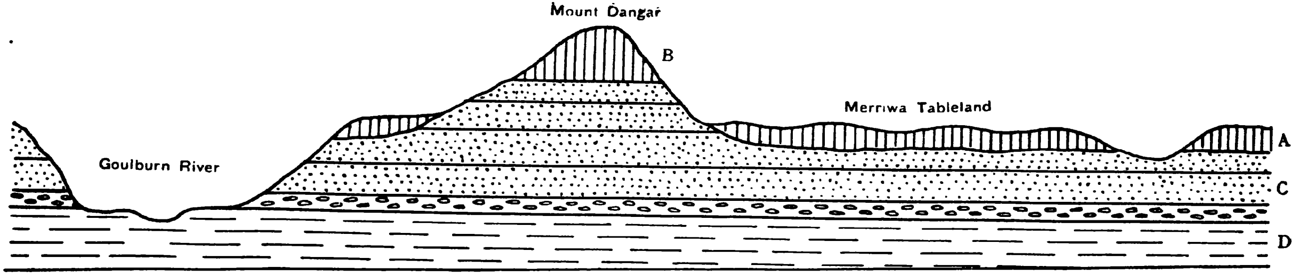

Mount Dangar
B
Merriwa Tableland
A
Goulburn River
C
D

Fig. 1—*Diagrammatic Section showing part of the Merriwa Tableland.*
A Plateau Basalts; *B* Monadnock Basalts; *C* Triassic Sandstones and Conglomerates; *D* Upper Coal Measures.

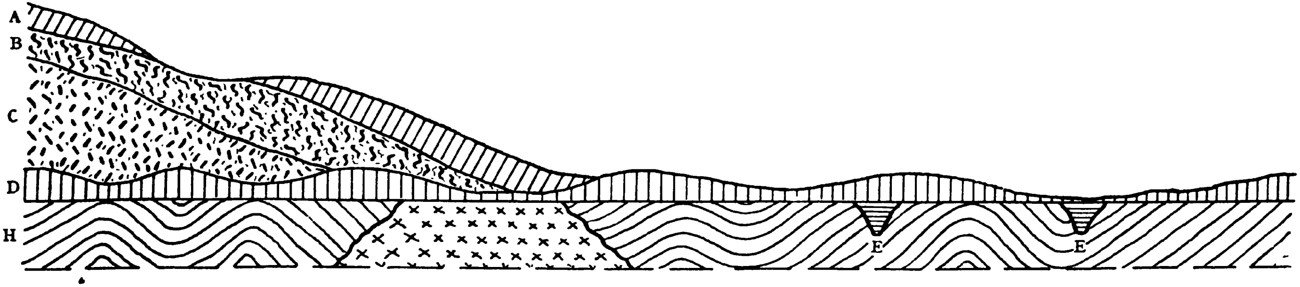


Fig. 2—*Diagrammatic Section in the Orange District showing part of the Canobolas Mountains.*
A Basalts and Andesites; *B* Alkaline Trachytes; *C* Comendites; *D* The Plateau Basalts; *E* Deep Leads with fossil fruits; *H* Palæozoic Complex.

capped by basalt over a very large area. It is proposed to call these basalts the Plateau Basalts, because both here and in many other places they form the surface layer of the present-day tablelands. The surface of the Merriwa Tableland, in common with the surfaces of the various other tablelands in eastern New South Wales, is a peneplain (the East-Australian Peneplain), which was elevated to its present position at the close of the Tertiary Period (the Kosciusko Epoch). This uplift varied in amount in different parts of the State, the Merriwa Tableland area being elevated only 1400 feet. Mt. Dangar is a monadnock, rising about 800 feet above the level of the surface of the Merriwa Tableland, and is obviously a residual of the earlier tableland out of which the East-Australian Peneplain was cut. It also is capped by basalt, and this basalt, if part of a flow, must obviously belong to an earlier geological epoch than the plateau basalts. Many such basalt-capped residuals occur in the Blue Mountain Tableland, and for these basalt cappings the name ''Monadnock Basalts'' is proposed.

The Plateau Basalts are everywhere found to be traversed by a system of broad, shallow, mature valleys, from 200 to 300 feet deep. This feature is not confined to the basalt areas, but is found wherever undissected areas of the East-Australian Peneplain occur, quite regardless of what the surface rocks may be. These will be referred to as the Upland Valley System. Cutting back into the present-day tablelands, and cutting across both the Plateau Basalts and the Upland Valley System are the valleys and gorges of the present cycle of erosion. In Fig. 2 is shown a section of that part of the Orange Tableland, upon which the Canoblas Mountains stand. Here, again, may be seen the East-Australian Peneplain, with its veneer of Plateau Basalts and its Upland Valley System; but in addition we have the volcanic pile of the Canoblas Mountains, with its alkaline lavas and tuffs deposited on top of both the Plateau Basalts and the Upland Valleys. This alkaline series belongs, therefore, to a younger geological epoch than the Plateau Basalts. In this section, also, is shown a deep-lead containing fossil leaves and fruits, underlying (and therefore older than) the Plateau Basalts. Summarising these various features in descending chronological order, we get the following:—

Close of the Tertiary Period	The Kosciusko Uplift.
Late Tertiary	The Alkaline Series.
Lower or Middle Pliocene	The development of the Upland Valleys, following a small uplift.
Upper Miocene or Lower Pliocene	The Plateau Basalts.
Lower to Middle Tertiary	The cutting out of the East-Australian Peneplain.
Early Tertiary	The Monadnock Basalts.
Upper Cretaceous	The cutting out of the Cretaceous Peneplain, followed by an uplift of from 600 to 800 feet.

A. The Monadnock Basalts.

These, as has already been explained, occur as cappings on residuals of the Cretaceous Peneplain. An important group of these residuals occurs on the northern part of the Blue Mountain Tableland. These include Kerry Mountain, Nullo Mountain, Mt. Coriaday, and Mt. Monundilla; the basalt cappings range from 100 to 300 feet in thickness. On the same tableland, but further to the south, is another group of these residuals. These include Mts King George, Bell, Tomah, Wilson, Irvine, and Hay. Here, again, the basalt cappings range from 100 to 300 feet in thickness. In several cases the basalts lie in definite stream channels, and overlie waterworn boulders, showing that in those cases, at least, the basalts are actual flows. The nature and arrangement of these occurrences indicate that this basalt at one time covered much more extensive areas than it does now. The basalt capping the Bald Hills near

Bathurst also belongs to this series, and here also they overlie river gravels. Analyses of some of these basalts are given in Table II.; their petrological characters have been fully described by Mr. G. W. Card.(28)

B. The Plateau Basalts.

These flows, naturally, have suffered much less denudation than the Monadnock Basalts, and still cover extensive areas of the northern, central, and southern tablelands, while the many remnants still remaining in many localities where the tablelands have been extensively dissected during the present cycle of erosion, show that the extent of these flows was originally much greater than it is to-day. The usual thickness of the Plateau Basalts is from 200 to 400 feet, but in parts of New England, notably in the McPherson Range, at Guy Fawkes, and on the Barrington Tableland, the thickness ranges up to 1000 feet. The Plateau Basalts are typically fine-grained, olivine basalts, but in some localities, notably at the south-western corner of the Barrington Tableland, coarse-grained olivine dolerites are interstratified with the ordinary basalts. There is, however, a probability, as suggested by Dr. W. N. Benson, of these dolerites being intrusive into the finer-grained flows.

From the Bingara Range, Dr. Benson has obtained the following section:—

	Thickness Feet.
Newer Basalts	350
River Sands and Gravels	120
Older Basalts	300
Sands, Clays and Gravels (with fossil fruits) ..	400

This section indicates that at least two different outbursts occurred, separated by a period of quiescence; both flows, however, belong to the Plateau Basalt Series. Sir T. W. E. David has similarly recorded the occurrence of two distinct flows at Emmaville, with an aggregate thickness of 300 feet, separated by 40 feet of volcanic ash. These flows overlie stanniferous deep-leads containing Tertiary fossil leaves.

On the Central Tableland, notable occurrences of Plateau Basalts occur at Gulgong and at Forest Reefs. At each of these localities the basalts overlie deep-leads containing fossil leaves and fruits. These fossil plants are important, as they are the only palaeontological evidence we have as to the actual age of our Tertiary volcanic rocks. There have been many differences of opinion as to the geological age of these plants; the question has recently been exhaustively studied by R. W. Wolcott,(70) and he places the age of them as being either Upper Miocene or Lower Pliocene. This also fixes approximately the age of the Plateau Basalts as being about the same. The Plateau Basalts are extensively developed on the Bowral-Mittagong Tableland, notably at Robertson, at Exeter, and at Wingello. At the last-named locality, they overlie Tertiary leaf beds. Still further to the south, they are extensively developed on the Berridale Tableland, in the Cooma District, and at many other places.

Volcanic ash deposits are associated with the Plateau Basalts to a limited extent. Their limited occurrence at Emmaville has already been referred to; they are, however, more strongly developed at Guy Fawkes, and in the McPherson Range.

It has usually been assumed that the Plateau Basalts resulted from fissure eruptions, and this may in general be true. Sir T. W. E. David has, however, recorded the existence of remnants of tuff cones in the Emmaville district, while the writer has noted the occurrence of several basalt necks in the Upper Hunter District, one near Gundy, one alongside the road from Denman to Merriwa, and another near Merriwa, while Dr. Benson has recorded the occurrence of several basaltic necks in the Nundle-Tamworth District.

C. The Alkaline Series.

Towards the close of the Tertiary Period, a number of isolated centres of volcanic eruption developed, from which a highly-interesting series of alkaline lavas was erupted. These eruptions built up groups of volcanic cones such as the Canoblas, Warrumbungle, and Nandewar Mountains. These occurrences of alkaline rocks are limited to the eastern tableland belt, and the eruptions appear to have immediately preceded the uplift of the tablelands (Kosciusko Uplift); and they are localised at points adjacent to lines of crustal warping or faulting. The volcanic rocks included in this series are nearly all highly alkaline, but the latest flows are either sub-alkaline or normal basalts. The order of eruption of the lavas at the three abovementioned centres was as follows:—

Canoblas Mts.	Warrumbungle Mts.	Nandewar Mts.
1. Comendites.	1. Comendites and Pantellerites	1. Comendites and Alkaline Rhyolites
2. Alkaline Trachytes	2. Aegirine-Trachyte and Phonolitic Trachytes	2. Alkaline Trachytes
3. Phonolitic Trachytes	3. Phonolites	3. Phonolites
4. Andesites and Basalts.	4. Trachy-Andesites	4. Alkaline Andesites
	5. Andesites and Alkaline Basalts	5. Alkaline Basalts

The earliest eruptions brought to the surface a series of acid alkaline and sub-alkaline lavas, which built up steep lava cones. Then came showers of volcanic ash and fragmental material, and this was in turn followed by the outpouring of the alkaline trachytes, phonolites, and trachyandesites in that order. Somewhat later, but without, apparently, any very great interval of time, these were followed by sub-alkaline andesites and basalts, and normal basalts. These last flows not only partly covered the earlier alkaline rocks, but in places, notably at the Canoblas Mountains, spread out on to the surrounding older Plateau Basalts. In our account of the Geology of the Canoblas Mountains, Dr. H. I. Jensen and the writer made the mistake of concluding that the whole of the basalts there belonged to one series, and to be younger in age than the alkaline rocks proper. Some years later, when the writer visited the district again in company with Mr E. C. Andrews, this matter was re-examined, and the conclusion arrived at that there were basalts of two ages present—(a) the Plateau Basalts, older than the whole of the alkaline series, and (b) a younger series of andesites and basalts, resulting from the final eruptions of the Canoblas Mountains. It is worthy of note that both at the Canoblas Mountains and elsewhere these latter basic rocks are in nearly all cases porphyritic in texture, whereas the Plateau Basalts are typically non-porphyritic in texture.

Dr. H. I. Jensen concurs with this conclusion, and considers that similar conditions exist at the Warrumbungle and Nandewar Mountains. He also considers that these younger rocks are basic differentiation products of a magma rich in Al_2O_3, Na_2O, and TiO_2, and poor in MgO and FeO; and that they are the last basic residuum of an alkaline magma. The petrology of the alkaline rocks of the Canoblas, Warrumbungle, and Nandewar Mountains has been fully described by Dr. H. I. Jensen.

The Macpherson Range.—The alkaline series are also developed in the Macpherson Range, along the eastern part of the boundary between New South Wales and Queensland. Dr. H. C. Richards (59) has sub-divided the volcanic series here as follows:—

3. The Upper Division { Olivine Basalts.
Andesites and Andesitic Basalts.
Basalts.

2 The Middle Series Rhyolites and Trachytes, and their fragmental equivalents.

1. The Lower Series—Normal and Olivine Basalts.

The basalts of the Lower Series I take to be the equivalents of the Plateau Basalts of other parts of New South Wales. Dr. Richards points out that the nature of the contact between this series and the one above indicates a very considerable time interval between the two. The Middle and Upper Series I consider to be the equivalents of the alkaline series already described from other parts of the State.

The Middle Division consists mainly of alkaline and subalkaline rhyolite and pitchstone with a very subordinate amount of alkaline trachyte. Fragmental rocks of the same composition occur both above and below the lava flows. These rocks attain their maximum thickness on the Springbock Plateau, where their thickness is 1,000 feet. At Mt. Lindsay there is a thickness of about 900 feet of pitchstones and tuffs, and these rest upon a thickness of 1500 feet of basalts and tuffs belonging to the Lower Series (Plateau Basalts).

The Upper Series consists of an alternating series of basalt and andesite flows. They attain their maximum thickness of 2,000 feet on the Lamington Plateau, where there are no less than twenty distinct flows. The above thickness, however, appears to be quite exceptional.

The Bowral District.—Two large masses of alkaline rock occur here, rising above the general level of the tableland, viz., the Gib Rock and Mt. Jellore. The Gib Rock breaks through and rises about 800 feet above the surrounding basalt-capped tableland, and consists of a fine-grained alkaline syenite allied to Bostonite. This is probably a partly-denuded lava cone. Mt. Jellore is a similar lava cone, consisting of an alkaline trachyte. Analyses of these two rocks are given in Table II.

It should be noted that while the alkaline series of volcanic rocks occur at quite a number of localities, the areas covered are so small relatively that the actual bulk of these rocks is quite small as compared with the bulk of the Plateau Basalts. Owing to their special petrological and chemical interest, they have received much more attention than the basalts, and this has given them a prominence which their relative quantity does not justify.

D. *The Leucite Basalts.*—These rocks have been recorded from a number of localities in the western districts of New South Wales. Professor T. W. E. David, (36) has recorded them from Byrock and El Capitan (Cobar District); Rev. J. M. Curran, (32) has recorded their occurrence at Harden; while G. A Stonier (62) has recorded them from Lake Cudgellico, also from Bygalore. In each case the area covered by them is not large, but they are unquestionably flows. The age of these flows has not been determined, but they have always been considered to be of Tertiary age. The description given by G. A. Stonier of the Lake Cudgellico occurrence suggests that it is not older than the Late Tertiary, and I have therefore provisionally placed them with the Alkaline Series.

The Pleistocene Period.

No volcanic rocks of Pleistocene age, with one possible exception, are definitely known to occur in New South Wales. Mr. L. F. Harper, (43) has suggested that all of the basalts of the Illawarra Tableland are of Pleistocene age, and mentions particularly those which occur at Sassafras, Wingello, Robertson and Cordeaux. The writer has examined the occurrences at the first three localities, and is of opinion that all three belong to the Plateau Basalt Series, and are therefore of Tertiary age; their mode of occurrence, and the physiographical features occurring both in the basalts and on the surrounding tableland are identical with those of the plateau basalts in all other parts of the State No opportunity has occurred for examining the igneous rocks which occur at Cordeaux; Mr. Harper(40a) describes these as being ophitic-dolerites and to vary from aphanitic to phaneric in texture; some portions are almost gabbroidal in texture. His description of the mode of occurrence implies that he considers it to be partly intrusive and partly effusive; this, taken in conjunction with the fact that the rock is a dolerite (coarse grained in part), raises the question as to whether the whole occurrence may not be intrusive; it would perhaps be better to suspend judgment until more definite evidence is available. No other reported Pleistocene volcanic rocks are known to the writer.

VIII.—Summary.

From the information given in the preceding pages, it will be seen that while a large amount of information is now available in connection with the volcanic rocks of New South Wales, very much has still to be learned. Our knowledge of the detailed petrology and distribution of the volcanic rocks of the Ordovician, Silurian, and Devonian Periods is quite limited. We have a more detailed knowledge of the volcanic rocks of the Carboniferous and Permo-Carboniferous Periods, but for certain districts only. Similarly with regard to the Tertiary Period we have a fairly complete knowledge of the Alkaline Series, but a quite limited knowledge of the Monadnock Basalts and the Plateau Basalts. Owing to these very numerous gaps in our knowledge, it is impossible to put forward any generalizations of real value; nevertheless, there are some interesting features which might be briefly referred to

The following table summarises the general features of New South Wales vulcanology:—

Summary of Volcanic Action.

Period.	Volcanic Rocks.	Conditions of Sedimentation.	Tectonic Conditions.
Cambrian	None known		
Ordovician	Andesites	Marine	Subsidence, with heavy sedimentation
Silurian	Rhyolites	Marine	Subsidence, with heavy sedimentation
Lower Devonian	Rhyolites	Terrestrial	Standstill, following uplift.
Middle Devonian	Rhyolites	Marine	Subsidence, with heavy sedimentation
Upper Devonian	Rhyolites and Basalts	Marine	Subsidence, with moderate sedimentation
Lower Carboniferous (Burindi)	Keratophyres	Marine	Subsidence, with heavy sedimentation
Upper Carboniferous (Kuttung)	Andesite to Rhyolite, acid rocks preponderating	Terrestrial	Uplift
Permo-Carboniferous	Basalts and Latites	Marine and Fresh-water	Intermittent subsidence, with alternating periods of relative stability and heavy sedimentation
Triassic	Basaltic (very limited)	Terrestrial	Standstill, with limited local subsidence
Jurassic	None known	Terrestrial	Standstill, with limited local subsidence
Cretaceous	None known	Terrestrial mainly	Standstill, with limited local subsidence
Lower Tertiary	Basalts	Terrestrial	Uplift and denudation
Middle Tertiary	Basalts	Terrestrial	Uplift and denudation
Late Tertiary	Alkaline Series and Basalts	Terrestrial	Uplift and denudation

A study of this table, taking the State as a whole, brings out the following features:—

I. The vulcanicity, so far as we know, started with intermediate volcanic rocks in the Ordovician Period. In the three succeeding Periods—Silurian, Devonian, and Carboniferous—the rocks were dominantly acidic; while from that on to the end of the Teritary Period, the volcanic rocks were dominantly basic.

II While volcanic activity was more or less pronounced throughout both the Palæozoic and Cainozoic Eras, it was a quite unimportant feature during the Mesozoic Era.

III. The composition of the volcanic rocks does not appear to have any definite relation to the particular tectonic conditions prevailing at the time of their formation; for example, acidic lavas are associated with conditions of subsidence in one period, and with conditions of uplift in another period.

IV. Pronounced volcanic activity does not appear to have been necessarily connected with heavy sedimentation, as during some periods it was associated with uplift and denudation; nevertheless, each period of extensive subsidence and marine sedimentation seems to have had more or less volcanic activity.

V. Volcanic activity ceased somewhere about the end of the Tertiary Period. There are neither active nor dormant volcanoes in New South Wales to-day.

VI. Both the plateau basalts and the alkaline volcanic series of the Tertiary Period occur in a region of epeirogenic uplift and block-faulting, but the outpouring of these lavas does not appear to have closely followed a period of pronounced uplift, but rather to have followed a long period of denudation; the aggraded river channels covered by the plateau basalts rather suggest that the vulcanicity followed a small subsidence. That the Tertiary alkaline series preceded and did not follow the great Kosciusko uplift is indicated by the fact that, as pointed out by Dr. H. I. Jensen, these rocks in the Nandewar Mountains have been displaced by the faults of the Kosciusko Epoch.

VII. The Tertiary Leucite Basalts do not occur in the region of mayor Tertiary crustal movement (the Eastern Tableland Belt) but appear to be limited in their occurrence to a relatively low-lying region (the Cobar Tableland), which appears to have been subjected to only relatively small uplifts during this period. This seems to parallel the occurrence of Leucite basalts such as those in the Malayan Arc and in Japan, which in both cases have been erupted in regions in the rear of the lines of main tectonic movement.

VIII. Eastern New South Wales has, throughout the Tertiary Period, been a very definite Petrographical Province; the basalts of the plateau series are all, so far as we know them, of a similar type; while the lavas of the alkaline series, as has been pointed out by Dr. H. I. Jensen (52), show remarkable similarity for all the localities where they occur. This Tertiary Petrographical Province extends well up into Eastern Queensland and southwards into Victoria. Similarly the north-eastern part of New South Wales was a very definite petrographical province, both during the Devonian Period and in the succeeding Carboniferous Period.

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NOTE ON THE DILUTION OF ETHYLENEBROMOHYDRIN WITH WATER.

By JOHN READ and GEORGE JOSEPH BURROWS.

[*Read before the Royal Society of N.S. Wales, June 6, 1923.*]

IN preparing aqueous solutions of pure ethylenebromohydrin for determinations of refractive index (Trans. Chem. Soc., 1920, *117*, 1222), certain interesting thermal effects were noticed upon mixing the two liquids at the ordinary temperature. Thus, a marked fall of temperature occurred on adding water to a considerable excess of ethylenebromohydrin, whilst in the preparation of more dilute aqueous solutions of the substance the thermal effect was reversed. The results of further observations, made with a limited amount of ethylenebromohydrin, are recorded in this paper.

Upon placing 10 grams of ethylenebromohydrin in a test-tube surrounded with cotton-wool and admitting water in successive small measured quantities from a burette, it appeared that a continuous negative thermal effect was produced until the attainment of a dilution of about 80 per cent., whilst at about 75 per cent. a positive thermal effect was manifested; this persisted to a dilution of about 10 per cent. Upon reversing the process and adding successive small amounts of ethylenebromohydrin to water, the initial positive thermal effect was followed in a similar way by a negative effect.

The data collected in an additional series of experiments, in which the liquids were mixed in small beakers surrounded with cotton-wool, are summarised in the appended table. In every instance, the solution was allowed to attain the temperature of the room before the addition of a further amount of either component.

Thermal Effects attending the admixture of Ethylenebromohydrin and Water.

Series.	Original liquid	Added liquid	Approximate percentage of bromohydrin		Alteration in temperature
			Original	Final	
I A	20 c.c. of bromohydrin	2 c.c. of water	100	94·6	– 2·0°
I B	20 c.c. of I A	2 c.c. of water	94·6	89·4	- 1·3°
I C	The whole of I B	2 c.c. of water	89·4	84·7	- 0·5°
I D	The whole of I C	2 c.c. of water	84·7	80·4	- 0·2°
II A	20 c c. of water	2 c.c. of bromohydrin	0	15·0	+ 0·7°
II B	The whole of II A	2 c.c. of bromohydrin	15·0	26·1	+ 0·4°
III A	20 c c. of water	6 c.c. of bromohydrin	0	34·6	+ 0·3°
III B	The whole of III A	2 c.c. of bromohydrin	34·6	41·4	- 0·4°
III C	The whole of III B	2 c.c. of bromohydrin	41·4	46·9	- 0·4°
III D	The whole of III C	2 c.c. of bromohydrin	46·9	51·4	- 0·1°

In endeavouring to account for these curious thermal phenomena it was considered advisable to determine the densities of a series of aqueous solutions of ethylenebromohydrin. The values obtained are recorded below, the necessary solutions of known concentrations having been prepared by direct weighing.

Densities of Aqueous Solutions of Ethylenebromohydrin at 20°.

Weight percentage of ethylenebromohydrin	D^{20}_{4} (vac.)	Weight percentage of ethylenebromohydrin	D^{20}_{4} (vac.)
100	1·7629*	36·664	1·1990
96·982	1·7253	30·206	1·1589
91·340	1·6591	22·441	1·1134
87·410	1·6165	20·040	1·1000
77·531	1·5163	18·810	1·0931
58·135	1·3490	15·044	1·0726
53.620	1·3147	10·010	1·0462
50·041	1·2887	5·011	1·0217
46·535	1·2640		

* The value previously quoted (Trans. Chem. Soc., 1920, *117*, 1221) for the densities of pure ethylenebromohydrin should read as follows (reduced to vacuum standard). D^{0}_{4} 1·7919, D^{15}_{4} 1·7701, D^{20}_{4} 1·7629, D^{25}_{4} 1·7556, D^{30}_{4} 1·7484. The mean coefficient of dilatation between 0° and 30° is 0·00083.

These results, when represented graphically, yield a regular curve of the same type as the refractive index-concentration curve for similar solutions (*loc. cit.*, p. 1223). The volume of the solution at any concentration is thus less than the combined volumes of the two components. The maximum contraction exhibited by the data listed in the above table occurs at the concentration 50·041 per cent., and it amounts to 1·07 per cent., calculated on the sum of the initial volumes of water and ethylenebromohydrin. It may be noted that this concentration corresponds very closely with the molecular ratio 1 C_2H_5O Br : 7 H_2O. In the case of the closely related substance, ethyl alcohol, the maximum contraction, which is more than three times as great as with ethylenebromohydrin, occurs at about 46 per cent. concentration at 15°, the corresponding molecular ratio being 1 C_2H_6O : 3 H_2O.

A similar series of measurements was made at 25°. In this case the maximum contraction was observed for a mixture containing about 46 per cent. of ethylenebromohydrin, corresponding approximately with the molecular ratio 1 C_2H_5OBr : 8 H_2O. Moreover, it was found that the viscosity increased regularly with an increasing percentage of ethylenebromohydrin. It would thus appear that density and viscosity measurements do not afford any evidence of hydrate formation. Furthermore, in view of the stability of ethylenebromohydrin in cold aqueous solutions (*loc. cit.*, p. 1225), it seems unlikely that hydrolysis is in any way accountable for the phenomena. It may also be added that the specimen of ethylenebromohydrin used in this work was free from hydrogen bromide.

It is hoped, as opportunity offers, to carry out more detailed and exact measurements of the changes involved and to extend the enquiry to related substances.

THE WARPED LITTORAL AROUND SYDNEY.

By Professor GRIFFITH TAYLOR, D.Sc., B.E. (Syd), B.A. (Camb.)

PART I.

[*Read before the Royal Society of N.S. Wales, June 6, 1923.*]

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Chapter I.—Introduction, Programme, Contours, Geology.

Chapter II.—Classification of Regions

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- B—Wianamatta Stillstand.
- C—Warp Lakes.
- D—Bottleneck Canyons.
- E—Nepean Ramp.
- F—Hornsby region of major dissection.
- G—Wingecarribee Core.
- H—Ourimbah Core.
- J—Illawarra Sapped Coast
- K—Valley-Wall residuals (Newport Coast).
- L—Tuggerah Sapped Coast.
- M—Wollondilly region of no settlement.
- N—Colo region of no settlement.

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Chapter IV.—Warping and Population.

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Fig. 1. Generalised zones of elevation.
Fig. 2. Generalised Geology.
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Chapter I.—Introduction.

I propose in a series of papers under the above heading to describe in some detail the chief topographic features of that most interesting country which surrounds Sydney. These studies have developed from a series of maps and models constructed in connection with the recently instituted Department of Geography at the University of Sydney. They are in great part based on the large model of the Sydney region, which is being built up by my students as rapidly as the military contour maps are issued by the authorities concerned. The excellent model by Mr. L. F. Harper of the Geological Survey carries our knowledge far to the south of the military maps, and I have found it of the greatest help both in teaching and in the present studies. Other acknowledgments will be made in the body of the papers.

Most of the research in the past along somewhat similar lines has rather stressed the geological aspects of the problem, and it is of course impossible to dissociate these from the purely topographic features. I will only refer to the classic papers by Professor Sir T. W. Edgeworth David on the Great Monocline at Lapstone Hill[1] (1896) and on the fault scarp at Kurrajong,[2] and to the numerous papers by Mr. E. C. Andrews, notably that on the Blue Mountains.[3] More definitely geographical are the papers on the Tablelands by Mr. C. A. Sussmilch,[4] and those of Mr. Charles Hedley on the submarine slopes and meridional drainage.[5] In two memoirs by myself ("Physiography of Eastern Australia," 1911[6] and "The Australian Environment," 1918),[7] I have attempted to summarise the general conclusions, and it is the purpose of the present papers to choose salient districts and investigate them in fuller detail.

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[1] Roy. Soc. N.S.W., 1896. [2] Roy. Soc. N.S.W., 1902.
[3] Linn. Soc. N.S.W., 1903. [4] B.A.A. Sc. Handbook N.S.W., 1914.
[5] Linn. Soc. N.S.W., 1910 and 1911. [6] Weather Bureau Bulletin, 8, 1911.
[7] Memoir I, Federal Council of Science and Industry, Melbourne, 1918.

Programme—I propose to commence by a *classification* of the topographic units into which the area may be divided. A marked *symmetry* of structure is apparent in the Sydney region, and this is discussed in the second part herewith. Then, will follow a study of *type regions*, of which Wentworth Falls, Jenolan, Mittagong, the Nepean Gorge, the Cattai outlet, Sydney Harbour, Broken Bay, the Narrabeen coast, Cronulla and the Bulli coast have already been investigated and illustrated by block diagrams. Some of these, together with other districts, are occupying the attention of my senior students; and hence I hope that the whole region will soon be better known than any other in our Commonwealth.

Main Contours—I have chosen as boundaries of the Sydney region the somewhat arbitrary limits shown in Fig. 1. On the south is included the Shoalhaven gorge and part of Jervis Bay; on the west the Great Divide is approximately the boundary, on the north the region extends to Tuggerah Lakes, while the Pacific Ocean limits it to the east.

The topography can only be accurately shown by contours in the north-east quarter, where the military maps now extend approximately from Camden to Lake Macquarie. Unfortunately this rectangle is incomplete in the north-west (around Windsor), though no doubt military contours will be available here in the near future. For the remainder of the Sydney Littoral we have various railway levels and trigonometrical data, amplified by special contour maps of small districts (such as Wentworth Falls) made privately.

Generally speaking, the 500 feet contour surrounds the central lowland which I name the "Wianamatta Stillstand." Thence it runs south, near the coast, along the Illawarra Scarp; and north, somewhat further from the coast, from French's Forest to Ourimbah.

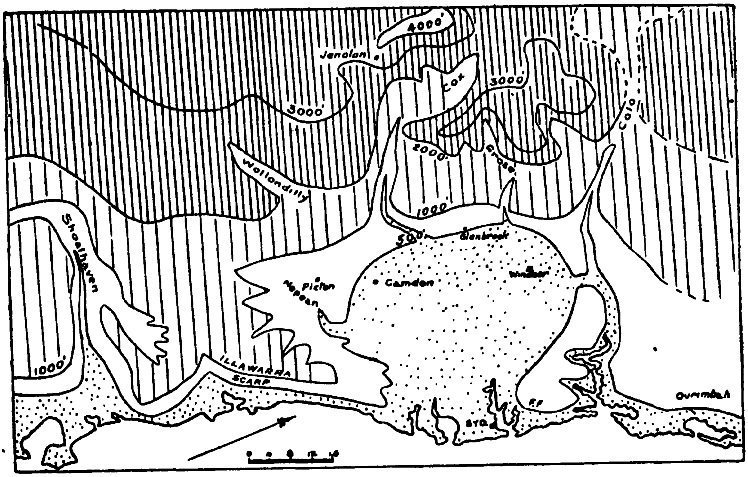
4000'
Jenolan
Cox
3000'
5000'
Colo
2000'
Grose
Wollondilly
1000'
Shoalhaven
500'
Glenbrook
Picton
Nepean
Camden
Windsor
Illawarra Scarp
1000'
F.F.
Syd.
Ourimbah

Fig. 1—Generalised orographic map. No contours are available for most of the area.

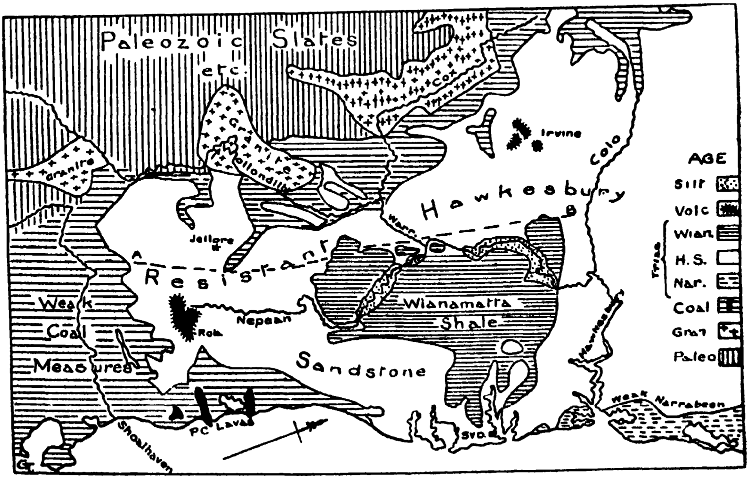
Paleozoic Slates etc.
Cox
Granite
Wollondilly
Granite
Irvine
Colo
Hawkesbury
B
Warr.
Jellore
A
Resistant
Weak Coal Measures
Wianamatta Shale
Rob.
Nepean
Sandstone
PC Lavas
Shoalhaven
Syd.
Hawkesbury
Weak Narrabeen
G.
AGE
Silt
Volc
Trias
Wian.
H.S.
Nar.
Coal
Gran
Paleo

Fig. 2.—Salient Geological features, from the official map. The coal is Permo-Carboniferous, the granite somewhat older and the slates chiefly Silurian.

The land rises in the southern half of the Stillstand fairly rapidly from 500 to 1000 feet; *i.e.*, in about ten miles along the railway line from Picton to Bargo. The 1000 feet contour also forms part of the Illawarra scarp. On the north of the stillstand, however, the 1000 feet contour hardly comes into the region; but on the west there is a steeper grade than on the south (*i.e.*, the rise of 500 feet occurs between Glenbrook and Valley Heights, a distance of about five miles).

The 2000 feet and 3000 feet contours run approximately north and south in the western portion of the region, but we have no accurate data except along the southern and western railway lines. The highest point is probably Mount Bindo (4460) near the Jenolan Caves.

Salient Geology.—Thanks to the efforts of the Geological Survey and of the Geological Department of the University of Sydney, the geology of the region is very well known. The map of the Sydney region (issued in 1903) has been very helpful in all geographical studies. I have illustrated the chief features in the small sketch map, (Fig. 2) and it is here sufficient to epitomise what will be discussed in detail later. It will be seen that the latest deposits occur in the central lowlands and that the oldest accompany the granites in the west. It is no less a geological than an ethical truism that the lowly are preserved, while the uplifted are cut down. Thus the recent silts of the 'Fossil Lakes' along the Nepean are preserved, while the uplifted gravels, of somewhat similar age, at Glenbrook and the 'Basin' are being eroded fairly rapidly. So also on a grander scale the Triassic shales of the Wianamatta series present an unbroken surface in the 'stillstand,' but have largely vanished from the uplifted margins of this lowlying area. In the higher regions covered by the Hawkesbury sandstone as at Katoomba and Mount Victoria (3000 feet), we find pinnacles, narrow necks etc., which are wanting in the lower portions of the same Triassic layer nearer Sydney. Other factors of course are concerned in the question of the relation of topography to stratigraphy. Under the resistant Hawkesbury Sandstone with its marked vertical joints, are two series of much weaker sediments. The Narrabeen series (chiefly shales) has determined the topography very largely along the coast north of Sydney; while the weakness of the coal measures and marine series of the Permo-Carboniferous has led to extensive 'sapping' beneath the Hawkesbury. This is a major factor in the evolution of the south coast plain and of the famous Blue Mountain Gorges.

Chapter II. Classification of Regions. (See Fig. 3)

A. *The Botany Region of No Uplift.*[1]—A study of the coastal features shows that Botany Bay is quite unlike any of the adjoining inlets, now invaded by the sea. Its plan is circular and its shores are low, on all sides passing gradually into shallow water, except near the Heads and at the inlet of George's River. Inland the topography is subdued and Cook's river exhibits senile meanders. A few miles to the west of Botany Bay are two small sheets of water of a somewhat similar type. These are Salt Pan Creek entering George's River (here salt) and Homebush Flats entering Parramatta River (salt). They also are drowned portions of the coast, *which had not previously been subjected to uplift* and consequently to rejuvenation. Thus our first subregion is an oval area extending approximately from Cape Solander to Parramatta (some eighteen miles). This area has clearly not participated in the dominant movement of elevation, which has affected almost all the Littoral.

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[1] Slight rejuvenation is apparent south of Marrickville, but it is insignificant in comparison with that obtaining elsewhere in the Littoral.

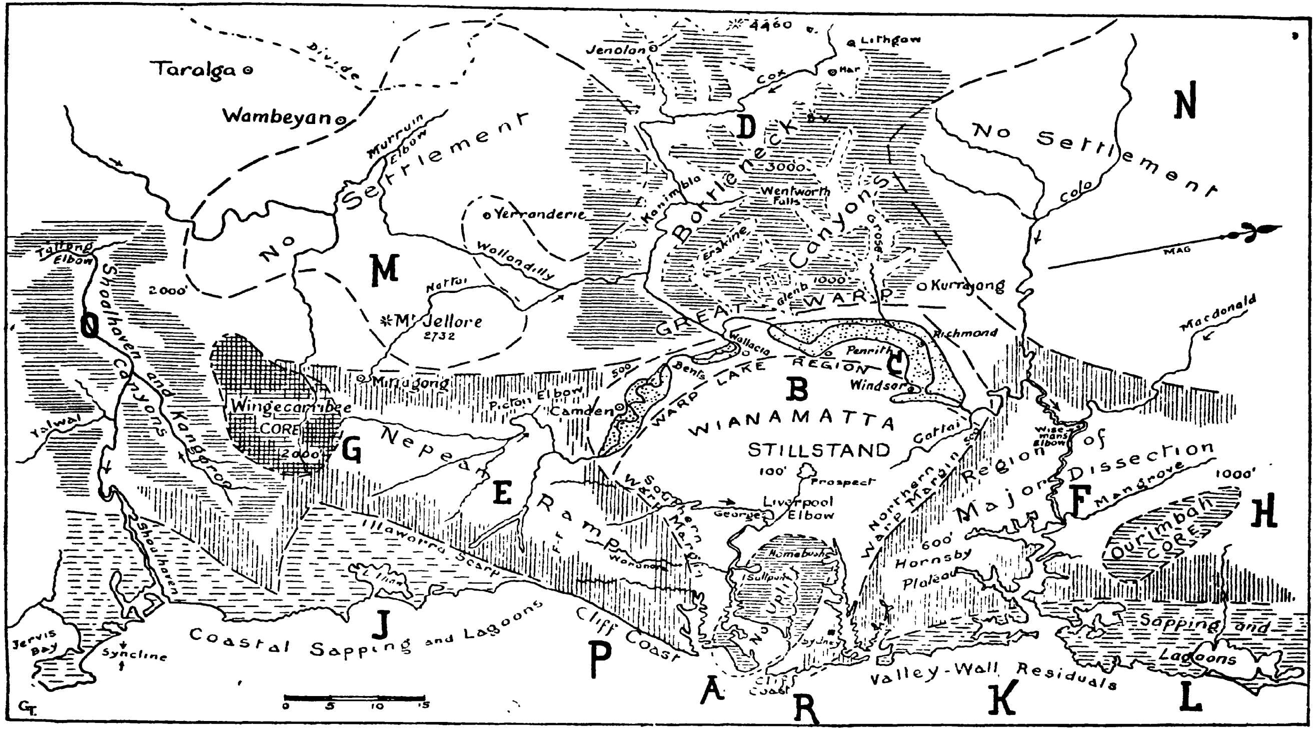
Taralga
Divide
Wambeyan
Murruin Elbow
No Settlement
M
Yerranderie
Wollondilly
Nattai
Mt Jellore 2732
Mittagong
Jenolan
4460
Lithgow
Har
Cox
D
Blue 3000
Bottleneck
Kanimbla
Wentworth Falls
Erskine
Canyons
Grose
Glenb
1000
Kurrajong
GREAT WARP
N
No Settlement
Colo
MAG
Macdonald
Tallong Elbow
2000'
Q
Shoalhaven Canyons and Kangaroo
Yalwal
Wingecarribee CORE 2000'
G
Nepean
Picton Elbow
Camden
500
Wallacia
Bents
Richmond
Penrith
C
Windsor
WARP LAKE REGION
B
WIANAMATTA STILLSTAND
100'
Prospect
Cattai
Liverpool Elbow
Georges
E
Ramp
Southern Warp Margin
Woronora
Northern Warp Margin
Region of Major Dissection
Wisemans Elbow
F
Mangrove
1000'
600'
Hornsby Plateau
Ourimbah CORE
H
Homebush
Sullpur
Sydney
Cliff Coast
Illawarra Scarp
Shoalhaven
Jervis Bay
Syncline
Coastal Sapping and Lagoons
J
P
A
R
K
L
Valley-Wall Residuals
Sapping and Lagoons
0 5 10 15
GT

Fig. 8.—Geographical Regions of the Warped Littoral around Sydney. N.B.—The 'warp margins' are about 5 miles wide.

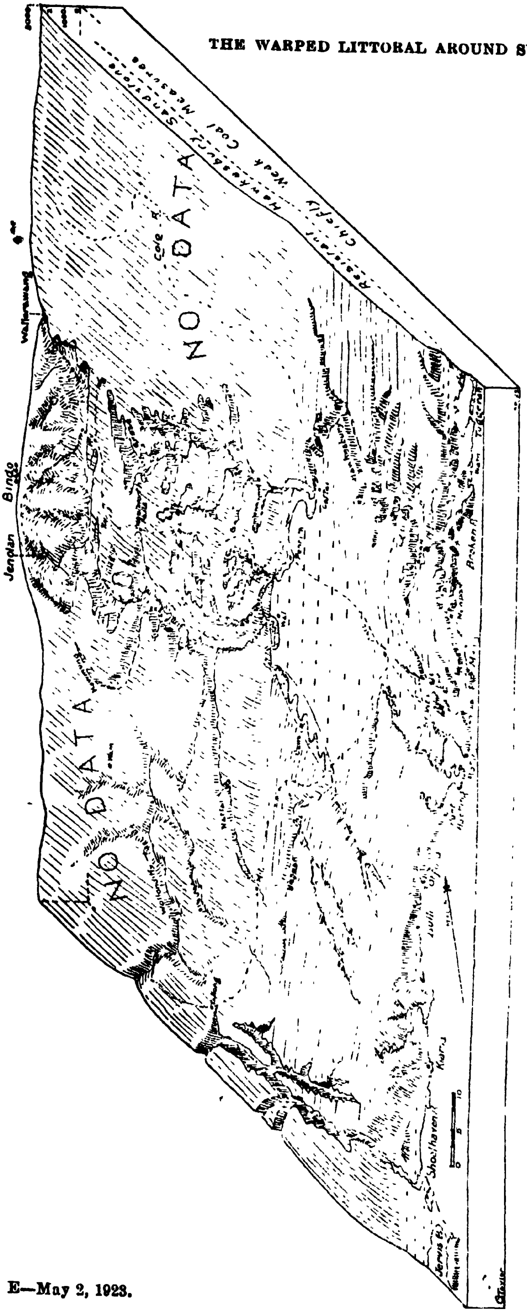
Wallerawang
Bingo
Jenolan
Cole R.
NO DATA
NO DATA
Hawkesbury Sandstone
Weak Coal Measures
Resistant Chiefly
Tuggerah
Broken B.
Kiama
Shoalhaven R.
Jervis B.
0 5 10
G. Taylor

Fig. 4.—Block Diagram of the Warped Littoral around Sydney, looking West. The heights are indicated in the N.W. corner and the strata at the right.

B. *The Wianamatta Stillstand.*—Somewhat similar features characterise the region to the west of that just described. From Parramatta to the foot of the great western warp is a region of subdued topography mostly only about 200 feet above sea-level, consisting almost entirely of weak Wianamatta shales. At the margins evidences of uplift begin to appear. Thus along the north we have the 'rejuvenated' cliffs of North Sydney; and the gorges of Lane Cove 'river' which contrast so greatly with the flats near by at Concord. Further to the northwest the Cattai region shows the Nepean rejuvenated by uplift. To the west is a specially interesting belt, that of the warp or fossil lakes, fronting the great western warp. To the south-west are the juvenile valleys of the Cataract and Nepean rivers near Picton. To the south-east is the convincing testimony of George's River, which leaves the uplift region just south of Liverpool, flows through the subdued topography of the 'stillstand' area around the sharp elbow at Liverpool, and soon re-enters the warp (near Holdsworthy) to continue therein until it enters Botany Bay.

C. *The Warp-Lake Region.*—This is really a sub-region of the preceding but is separated because it consists essentially of an extensive series of river silts, probably of Pleistocene and Recent age, which have been deposited in a chain of shallow basins along the course of the Nepean River. These basins recall (in miniature) the foredeeps flanking most mountain arcs.

There are three of these silt-areas, each terminating at a rocky gorge where the Nepean leaves the senile topography of the silts and immediately becomes markedly juvenile in its valley sections. The Nepean in pre-uplift days swung in wide meanders over the Wianamatta stillstand. The warping bisected some of these large meanders, so that the western portion of a meander rose to heights of several hundred feet while the eastern portion remained steady, or possibly sank slightly. Thus temporary lakes would develop readily, and in course of time become entirely silted up. The largest 'lake' (from near Penrith to Cattai) was dammed in similar fashion by the northern 'Hornsby' Warp rising athwart its course. The obstruction was obviously only *temporary*, or the Nepean would have taken a short cut to Sydney Harbour, along the course of the railway line (rarely 100 feet high), instead of penetrating the rising plateau (750 feet) to the north.

D. *The Bottle-neck Canyon Region.*—This includes the well-known gorges and valleys of the central Blue Mountain plateau. The area rises from near sea-level at Penrith (89 feet) to some 4000 feet in the west. There is some evidence of several 'steps' in the monocline. Level areas of considerable extent seem to occur about Glenbrook and Hazelbrook, but contouring is necessary to establish these steps. A still lower step of some 300 feet is apparent west of Wallacia. The salient features are the great valleys some 2000 feet deep and at times ten miles wide, which alternate with relics of the original land surface. Four of these bottle-necked valleys, ranging from the smaller Glenbrook canyons up through the Erskine and Grose to the giant Kanimbla (Cox), are illustrated in the maps.

The character of the stratigraphy consisting of resistant and almost horizontal Triassic sandstones, overlying weak shales—combined with the comparatively recent warp of some 4000 feet has led to the evolution of these unique bottle-neck valleys, whose evolution is described elsewhere.[1]

E. *The Nepean 'Ramp.'*—This region extends from the Wianamatta Stillstand to the south to the Shoalhaven

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[1] See Federal Handbook 1914. p. 95. Recent fieldwork leads me to believe that much of the canyon-cutting occurred when the rivers flowed to the west.

Basin. It rises very regularly from sea-level at George's River to 2000 feet at its southern edge. There seems to be no marked 'warp' or step, such as marks the great western warp; or the northern warp up to the Hornsby Plateau. Hence I have used the word '*ramp*,' to imply this steady rise or tilt. Minor scarps may occur—one is visible behind Otford running approximately east-west—and local ranges such as Razorback near Picton; but the land surface in this region seems to have been tilted up uniformly *as a whole* to the south. The drainage does not quite conform to this tilt, running obliquely across to the north-west. Many of the streams rise on the flat top of the precipitous cliffs (1000 - 2000 feet high) of the Illawarra scarp. The topography is much less dissected than in the other two warped regions. It is on the whole early-mature or adolescent, but becomes less and less eroded as we pass to the south. This may of course indicate that this warp is later than the Hornsby warp, and much later than the 'Blue Plateau' warp. The Nattai at Mittagong is in accord.

F. *The Hornsby-Hawkesbury Region of Major Dissection.*—This uplifted area has a general elevation of six or seven hundred feet. The warping is well marked along the north margin of the Wianamatta Stillstand in a belt about six or eight miles wide; but from Hornsby northward the elevation increases slowly from 600 feet to 900 feet behind Ourimbah. The dominant feature is the profound dissection, whereby the whole area is cut up into branching canyons five or six hundred feet deep. This is primarily due to the presence of the largest river of the region (the Nepean-Hawkesbury), which traversed the centre of the area, and tapped every portion with one or other of its tributaries. The region has been subjected to several oscillations; for the major uplift of 800 feet was followed by a subsidence of some 200 feet,[1] and then by an uplift of ten or twenty feet. This is clear from a consideration of the valley sections and their silt contents. [These are to be described in a later paper.]

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[1] Or drowning on Daly's hypothesis.

G. *The Wingecarribee Core.*—This oval area, about 20 miles long, is a subregion of the Nepean Ramp. It illustrates clearly a stage in the dissection of an uplifted peneplain which has not been sufficiently stressed in my opinion. It is obvious that immediately after its uplift a peneplain still exhibits a senile topography, though it is in a 'precarious' position and will soon yield to the headward erosion attacking it on all sides. This stage I have been accustomed to name a '*besieged peneplain.*' For long ages the *central portion* of the besieged peneplain remains in much the same condition, and the Wingecarribee swamps near Robertson illustrate the relics of such a besieged peneplain. For such areas I suggest the word '*core.*'

H. *The Ourimbah Core.*—A somewhat similar example occurs to the west of Ourimbah where the northern tributaries of the Hawkesbury and coastal streams like Wyong Creek have not yet dissected the original pre-uplift land surface, though profound dissection occurs on all sides of the 'core.' This small area is about five miles long, but is much less subdued than the Wingecarribee core. It thus seems to indicate that the lower Hawkesbury region had not reached so late a stage of peneplanation as had the upper Nepean region before uplift.

J. *Illawarra Region of Sapping and Lagoons.*—This area extends southward from the Otford Pass to Jervis Bay. It is the low-lying area, only one or two hundred feet above sea-level, which lies between the Illawarra Scarp and the sea. Its width increases regularly to southwards in accord with the thickness of coal measures exposed above sea-level. Thus at Coal Cliff the softer coal measures are little above sea-level. The coastal streams have had small opportunity to sap under the resistant Hawkesbury sandstone, and the coastal plain is consequently very narrow.

Behind Bulli the weak strata extend some 400 feet above sea-level, and the coastal plain is two miles wide. At Mount Kembla the weak strata are 800 feet high and the plain is here five miles wide. It is widest where the Macquarie rivulet has apparently cut back a deep re-entrant into the scarp. To the south the ancient lavas of Kiama have 'stiffened' the scarp, and this may account for the narrow plain hereabouts. South of these it widens greatly at the estuary of the Shoalhaven River. Here indeed we reach beyond the capping of resistant sandstone; and so there is no well-defined scarp south of the large river, like the Illawarra scarp.

The coast consists of an alternation of low capes and crescentic beaches. The oscillation of the coast is indicated by the sand-bars, lagoons, and fossil lagoons, which Harper has described at Coolangatta and Terragong.[1] He also shows that Jervis Bay is a drowned syncline in the Nowra grits, whose axis runs north and south, parallel to the Western Warp.

K. *The Region of Valley-Wall Residuals.*—This is a sub-region of the foregoing. All along the coast north of Sydney almost to Tuggerah we find a chain of 'rock-islands' linked to the mainland by isthmuses of sand or of very low rock strata. Examples are found in the South Head 'Island' isolated by the Bondi Golf-links, and the North Head Island isolated by the Manly Corso. There is a very typical series north of Newport at Bilgola, at Careel and at Barranjoey. Less striking examples, which however also illustrate their evolution, occur at Collaroy, at Terrigal and Wamberal.

These rock-islands are primarily not in my opinion due to marine erosion, but result from the breaking down of the eastern walls of a series of north-south gorges which emptied into the 'Sydney Harbour River' in the south, or into the Hawkesbury by the ancient 'Pittwater River,' etc. in the north.

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[1] "Southern Coalfield."

The process can be seen in three or four stages of evolution at the present time. Thus Cowan Creek shows the original structure of such a gorge. Pittwater shows the same type of valley with most of the eastern wall removed by the sea. The rock-islands represent 'spurs' or 'subdivides.' The north and south heads of Port Jackson are later stages, where very little of the original gorge or valley remains, (as the Corso and Golf-links at Bondi, respectively). Terrigal and Wamberal headlands show similar residuals where the upper portion of the gorge is attacked by the sea—the remainder has long vanished beneath the sea.

L. *Tuggerah Region of Sapping and Lagoons.*—Almost exactly similar conditions to the north of Sydney have led to a type of coast like Illawarra. Here however it is the softer Narrabeen shales (Triassic) which have enabled the creeks to sap back rapidly wherever they outcrop above sea-level. Since the warp here (unlike the Illawarra coast) has produced a fairly *level* plateau north of Narrabeen, we find that the sapping has extended back fairly uniformly for about eight miles from the coast. Small residuals stand up in the Kincumber region above the coastal plain. Tuggerah Lake corresponds very closely to Lake Illawarra in size and origin, but the original drainage (north-south) of the northern coast and its hinterland, differs materially from that of the Illawarra coast, and hence some noteworthy differences have arisen.

M and N. ***The uninhabited regions of the Lower Wollondily and Colo Rivers.***—These have been very inadequately investigated, and the writer has only viewed them from the volcanic summits (see Fig. 2) of Mount Jellore (south-west) and Mount Irvine (north-west). The Colo region is in the Hawkesbury Terrain, and is even more dissected than the adjoining Bottle-neck Canyon region. The Wollondilly region is largely carved in older Palæozoic slates, etc., and here the absence of jointing and the weaker tilted strata have led to a different, and in general more subdued facies. The chief feature, common to both, is their deserted character. This must be almost unique in a region of good rainfall, which is within fifty miles of a huge city of a million British people. The poor soils, but especially the juvenile dissection, hampering all communications, account for the lack of settlement.

O. *The Region of the Shoalhaven Canyons.*—The borders of the Hawkesbury Sandstone to the south (as in the case of the Hunter in the north) are marked by the headward erosion of a powerful coastal stream—the Lower Shoalhaven. This has cut a gorge 1600 feet deep—one of the finest in Australia—and so captured several rivers which flowed westward or north-west before the late(?)Pleistocene uplift. Yalwal Creek to the south, and the Kangaroo River (with Bundanoon and Tallowa Creeks) to the north have also cut down their valleys into canyons of lesser depth. Very fine outliers are preserved in the Cambewarra range which recall the similar outlier of Mount Solitary in the Kanimbla Canyon. But there is a very great difference between the width of the western Bottle-neck Canyons and the relatively narrow gorges of the Shoalhaven system. The latter river has cut back its gorge for some twenty or thirty miles south of the Tallong Elbow—but this is beyond the boundary of the region under investigation. It shows us however, that the Sydney warp is continued far to the south of the borders of our map.

P. *The Region of Rock Cliffs near Botany Bay.*—There is a great difference in the appearance of the coast of the

State between Otford and Manly and all the remainder included in the survey. It consists of almost vertical walls of sandstone, which are breached (where large creeks once opened) at Port Hacking, Botany and Port Jackson; but which elsewhere rise from 100 to 500 feet high.

Small coves and chines fret the cliffs, often where basalt dykes have weathered. Very fine examples of this structure occur south of Cape Solander—where a 'twin' chine was shown to me by Mr. Charles Hedley. The cliffs depend of course on the relative elevation of the stratum of Hawkesbury Sandstone. Where it has been warped down (or least elevated) as near Cronulla Beach, the cliffs are non-existent. It rises on the north to 300 feet at North Head and to somewhat higher elevations south of Garie Beach. These cliffs are bounded to the south by the 'Otford Pass,' where the streams draining north to Port Hacking have cut through the sandstone at their headwaters down to weaker strata, so that here small bottle-neck valleys may arise in the near future.

Chapter III.—Symmetry of the Regional Map. (Fig. 3.)

A rather remarkable degree of symmetry is observable in the topography of the Sydney Littoral. This exerts a strong geographical control upon the settlement, and a brief discussion of this symmetry will enable the evolution of the topography to be more readily grasped.

If we draw a line almost due west from Botany Bay, and follow the western railway line to Wallerawang, we shall find that the topography is symmetrically disposed about this east-west axis. Let us first follow the axis westward from the Boat Harbour near Cronulla. Here the top of the Hawkesbury Sandstone sinks to sea-level, (indeed the reef at Boat Harbour probably consists of the upper layers) while as we have seen everywhere else along the *main* coast-line it is much higher. Moving westward we cross the drowned *circular* plain of Botany Bay—where there is evidence that *no uplift* preceded the drowning. The Hawkesbury Sandstones are dipping to the west, as is evident in the the cliff near Kurnell. The sand dunes of Cronulla probably fill up the warped gap where the sandstone sank or was drowned.

Some 15 miles inland, one on each side of our axis appear the drowned *rounded pools* of Saltpan Creek and Homebush Flats. We pass westward across the middle of our Wianamatta Stillstand. The Hawkesbury Sandstones are here buried beneath 600 feet of Wianamatta shale. (Probably, however, *this* warping occurred very largely in Triassic times). Proceeding west we find at Penrith a large silt-lake on the north, and two smaller examples of similar origin just to the south. These occupy a sort of 'trench' below the great Western Warp. We rise up this warp between the Kanimbla Bottle-neck on south and the Grose Bottle-neck on the north. Finally at the extreme west of our region is Mount Bindo, perhaps the highest point (4460 ft.) in the whole area.

Let us now consider the disposition of our topographic units at some little distance from the 'axis of symmetry.' On the coast-line, immediately to the south is the drowned estuary of Port Hacking. Its 'fern-leaf' plan and general elevation resemble those of Sydney Harbour. The higher 'north shore' of Sydney is paralleled by the higher south shore of Port Hacking. The cliff coast of the National Park (at Garie etc.) is reproduced to the north in the cliff coast of Coogee. The same east-west faults, often occupied by basalt dykes, occur in both sets of cliffs. The coastal sapping is symmetrical also south and north, in the Illawarra and Tuggerah regions. The same type of .lagoons occurs, as described previously. Slight asymmetry occurs since the ancient lavas of Kiama do not occur in the north;

nor can the 'valley-wall residuals' develop in the south where the drainage is not parallel to the coast. We may compare the Shoalhaven Canyons with the canyons of the Hawkesbury, if we remember that several hundred feet of the latter are buried beneath the sea.

A north-south traverse across the axis about thirty miles inland reveals a similar symmetry, for the 'core' of undissected peneplain at Wingecarribee is paralleled by the 'core' behind Ourimbah. The gentle slope to the north of the Nepean tilt corresponds to the southward slope of the northern warp at the Cattai, but the uniformly *northward* flow of the Nepean from Wingecarribee to Wisemans Ferry has of course somewhat lessened the closeness of the symmetry. The 'Great Warp' runs apparently north and south. There is some differential movement between the Nepean Ramp and the Western Warp for the Nattai River enters the warp at Mittagong and is rejuvenated thereby. Picton Lakes (which I have not visited for many years) seem to correspond somewhat to the Lagoon at Kurrajong; but the new geological map which Mr. T. Willan has nearly completed, should settle this point. If it were not for these minor examples one would be disposed to describe the Sydney Littoral as essentially dominated by a crustal 'dimple' or centro-clinal trough developing in the same area as, though to a lesser extent than, the Triassic trough in which the Wianamatta Shales were deposited some 100 million years ago.

Chapter IV.—The Effect of the Warpings upon the Distribution of Population.

The last example of symmetry is seen in the western portion of the region. Here the Wollondilly 'desert' to the south of the axis corresponds to the Colo 'desert' to the north. The reason is fairly obvious. If it were not for the need for quick communication between Sydney and the

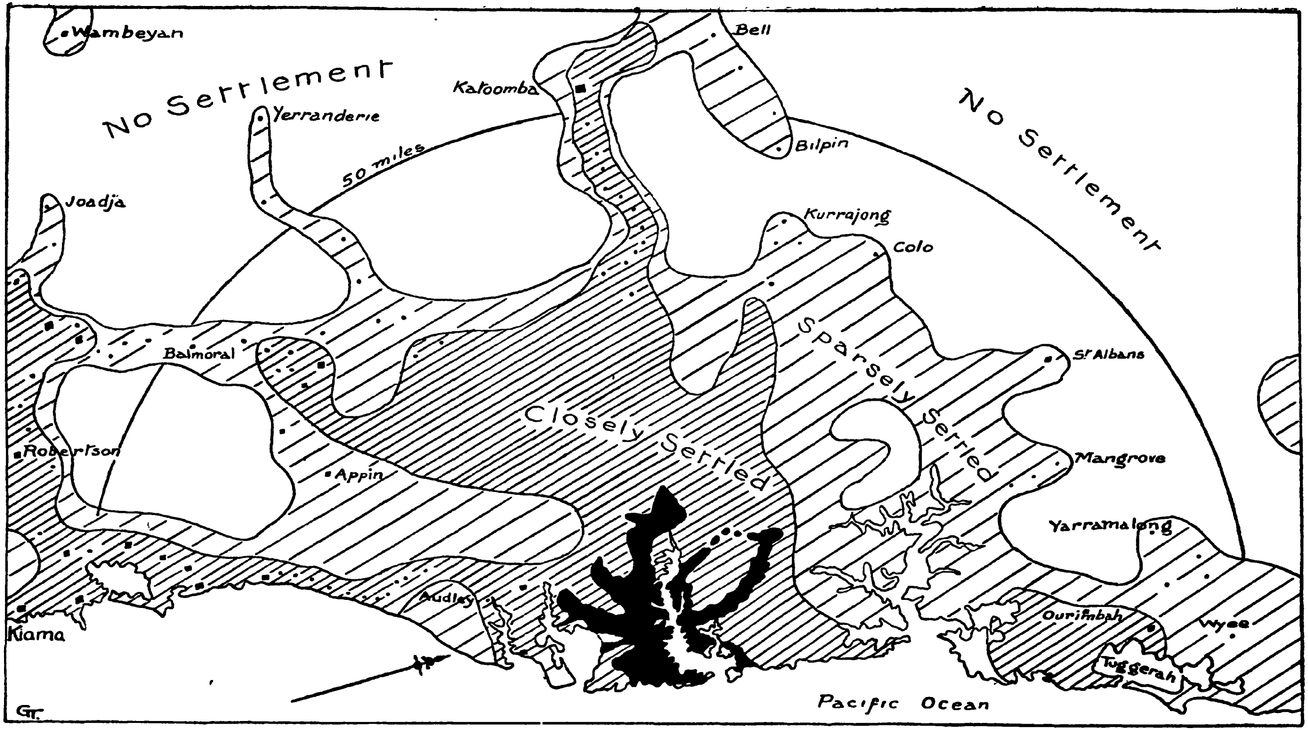
Wambeyan
No Settlement
Yerranderie
Katoomba
Bell
Bilpin
No Settlement
Joadja
50 miles
Kurrajong
Colo
Balmoral
St Albans
Sparsely Settled
Closely Settled
Robertson
Appin
Mangrove
Yarramalong
Audley
Kiama
Ourimbah
Wyee
Tuggerah
Pacific Ocean
GT.

Fig. 5.—The Distribution of Settlement. Region of city streets, *black*. Region where centres are less than about *four* miles apart, close ruling. (N.B.—Closely settled areas begin again somewhat to the west and north of this map).

Bathurst region there would be very much less settlement even in the Katoomba-Glenbrook 'oasis.' The railway crosses almost the highest and widest portion of the central (Blue Mountain) massif of our coastal highlands.[1] [Much better routes to the west exist viâ Cassilis (not yet used) and Goulburn.] No doubt tourist resorts, determined by elevation very largely, would have developed here in any case. Hence, if, as we shall see, the warping has determined the site of Sydney, we may also assert that Sydney has determined that the sole settlement on the western warp shall occur along the axis of symmetry, where the highlands are nearest to the metropolis.

In concluding this section we may note the topographic controls which led to the choice of the site of Sydney. As I have stated elsewhere, Newcastle has many advantages which are absent at Sydney—but as far as the region of our survey is concerned there are only three localities where fairly suitable sites occur. These are close together *e.g.*, at Botany Bay, at Port Hacking and at Sydney Harbour. Everywhere else the warps isolate the coast almost entirely from the interior. Indeed, from Newcastle to Nowra (150 miles) there are only five main roads (all south of Otford) which climb these scarps.

Botany Bay offers few facilities for deep frontages—for its shores have not been rejuvenated. Port Hacking receives several large streams which carry down much silt. These render the Port much shallower than Port Jackson. Finally the latter port extends so far inland that its headwaters (near Parramatta) reach into the plains of the Wianamatta stillstand. So that a much clearer path to the latter is offered behind Sydney, than behind Port Hacking. One wonders what would have happened if Captain

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[1] Indeed, but for the short Warragamba gorge, a much finer railway route to Wallerawang and the west follows up the natural drainage (without unnecessary ascent and descent) viâ Cox River.

Philip in 1788 had gone south instead of north on his arrival at Botany Bay. If our metropolis had oncebe en located near Audley, should we ever have managed to change it?

Sydney has a fine site in so far as its deepwater port is concerned. In passing, one may note that the Hawkesbury estuary is three times as picturesque as Sydney Harbour—for its dissection is three times as deep. There is unfortunately only a small hinterland to Sydney, *i.e.*, where the warping has not developed. The only really fertile regions are the small silt-lakes at Camden, Wallacia and Richmond along the Nepean. Here were the old "Cowpastures" and the finest farms of the pioneers.

In every other direction we are cut off by fairly sterile dissected plateaux. To the north is the barrier of the Hornsby Plateau, of very little use for primary production. The same is true to a greater degree of all the west. To the south the dissection is a little less advanced, and so we find a few small towns strung along the Great Southern Railway (such as Balmoral) before the more level land at Mittagong is reached.

If we draw a circle of 50 miles radius (see fig. 5) about Sydney (with its million inhabitants) we find therefore one of the most singular dispositions of circum-metropolitan population in the world. Let us suppose we survey this circular belt from an aeroplane. On the north our flight leaves the narrow coastal plain at Wyee. Thereafter for eighty miles along our circle we cross only one good road, which runs from Wisemans Ferry to Wollombi viâ St. Albans. The next twenty miles crosses Bell's Road (near Bilpin and Mount Irvine) and brings us to the Katoomba tourist belt. Proceeding south for forty miles we notice the single settlement of the Yerranderie mines, before we reach the southern line near Balmoral. Another twenty miles stretch of uninhabited water-reserves brings us to the narrow coast plain near Kiama, and here again a closely settled region is observed. Thus, excluding the shore, during a flight of over 150 miles we have only crossed two narrow belts of settlement (at Katoomba and Balmoral), while circumnavigating the largest town in Australia.

We see (from fig. 5) how important are the geological and geographical controls in the hinterland. The Robertson dairy farmers owe much to the late Tertiary volcanoes, and to the level *undissected surface* of the 'core.' The Katoomba belt of population is essentially based on *elevation* due to the warping. The Ourimbah region contains farmlands based on the *weaker series* below the Hawkesbury sandstones.

The closely settled region behind Sydney depends on the Wianamatta *shales*. Even in the city itself, the city spreads along the little-warped south shore of the harbour where traffic is easier; while the chief residences spread along the northern warped shore, where the elevation is greater and the scenery better.

In conclusion the author would draw attention to the very real need for completing the contour maps of the Sydney Littoral. Since the strata are so nearly horizontal the contours are a valuable clue to the arrangement of the mineral deposits below. Thus the Geological Survey is very wisely carrying out a rapid 'form-line' survey which will be found a valuable adjunct to detailed geological mapping. It is a great pity that every government land surveyor is not instructed to indicate the 'form lines' in a similar fashion on his maps. We should thus save thousands in the improvement in the laying out of roads alone.

I trust that it will be agreed that this preliminary paper shows that the warping of the Sydney Littoral has influenced and will influence in a most marked degree the development of our capital city.

THE GERMICIDAL VALUES OF THE PRINCIPAL COMMERCIAL EUCALYPTUS OILS AND THEIR PURE CONSTITUENTS, WITH OBSERVATIONS ON THE VALUE OF CONCENTRATED DISINFECTANTS.

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[*Read before the Royal Society of N. S. Wales, June 6, 1923.*]

IN view of the interesting results obtained by us in the examination of the residues from the steam rectification of the crude oil of *E. cneorifolia* and the high co-efficients of the pure 'active' constituents,[1] it was deemed advisable to proceed further and determine the co-efficients for the principal commercial Eucalyptus oils on the market, as well as for their chemically pure constituents. Since the publication of Dr. W. H. Martindale's work in the "Perfumery and Essential Oil Record" of November 1910, pp. 266–274, on the antiseptic power of Essential oils, practically nothing or very little has been done in the way of extending such work. On account of the necessity for some information on the germicidal value of pure organic chemicals[2] it was thought that a determination of the co-efficients for essential oil constituents would be of value as a preliminary investigation. In a second paper it is proposed to treat of other Australian essential oils, exclusive of Eucalypts, and their principal constituents, as well as other essential oil isolates and synthetics.

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[1] This Journal, LVI, (1922), pages 219–226.

[2] Dr. H. T. Calvert, Annual Reports S.C.I., (1921), Vol. VI, p. 511.

Apart altogether from this phase, there are a number of proprietary Eucalyptus oil disinfectants on the market, the composition of which is most variable, and up to now no knowledge has been available as to which constituent or constituents were responsible for their germicidal property, particularly as their content of cineol is usually low. Many such preparations, whilst compounded from the oils of *E. dives* and *E. phellandra*, contain, in the great majority of cases, large quantities of the residues left after rectification of the pharmaceutical oils, and as previously shown the active components are very often present in the latter. It is the utilisation of these residual oils that renders the manufacture of such disinfectants remunerative. Therefore, it is obvious that manufacturers do not maintain these preparations of constant composition, with the result that different samples of one preparation possess variable co-efficients. It is hoped that the table of co-efficients of the commercial Eucalyptus oils and their principal constituents as given under "Experimental" will assist manufacturers to produce a standard article.

Experimental

The Rideal-Walker tests were carried out exactly as described in our paper read before the Society on 6th December 1922, the standard organism, *Bacillus typhosus* being used. Standard suspensions of 1% of the crude oils and their pure constituents were made in 7½% rosin soap solution. To avoid detailing particulars of the crude oils and the methods of preparing the principal constituents in a condition of purity the chemical and physical constants are summarised, together with the co-efficients, as determined, in Tables 'A' and 'B' respectively. The constituents were either freshly prepared, or redistilled and purified, and the suspensions prepared immediately and tested.

The results show the crude oils containing piperitone, piperitol and the aromatic aldehydes to be superior to cineol oils in respect of their germicidal properties. In this connection, the crude oil of *E. hemiphloia* which contains only a trace of cineol, but 2% australol and 10% aromatic aldehydes, has a co-efficient of 7, but is not a commercial oil. Although very plentiful around Sydney the spread of population has caused it to be cut out, and the low percentage yield of oil (0·5%) and content of cineol rendered it of no importance. On this account it was tested in order to demonstrate that in the future clearing of large holdings it would be worth while distilling the leaves to convert the oil into a disinfectant. On the other hand, *E. dives* is now too valuable for disinfectant purposes as the piperitone is required for the manufacture of thymol which is being very successfully carried out in Sydney. The high co-efficient, however, for the oil of *E. radiata (E. numerosa)* should be the means of directing attention to its value. Prior to the demand for piperitone and the slump in mining both the oil of *E. dives* and *radiata* found use for flotation, principally the former, but latterly there has been no demand at all for the last named. This tree is particularly abundant in certain districts of this State and as the yield is high, distillers are awaiting its demand. A good field is, therefore, open for the production of a high co-efficient disinfectant from this oil, particularly as piperitol and its acetic acid ester impart to it a pleasant odour.

Eucalyptus Constituents, Table "B."

The results obtained to date tend to show that so far as the Eucalypts are concerned, terpenes, such as pinene, phellandrene, and limonene, sesquiterpenes and sesquiterpene alcohols possess poor germicidal properties, whilst ketones (taking piperitone as a type), alcohols (piperitol and geraniol as types), aromatic and open chain aldehydes (cuminal, citral and citronellal as types), and phenols (represented by australol) possess well marked germicidal properties.

Concentration.—In our previous paper we pointed out that "the co-efficiency increased with the dilution." The dilution, however, must be made when the soap solution is added, otherwise no increase takes place. The observation was accordingly followed up on account of its economic bearing. Disinfectant preparations are sold in a concentrated form for use in a diluted condition, and the co-efficients were therefore determined for both concentrations (See Table "C.") These results show that a different procedure will need to be adopted in the future when determining the Rideal-Walker C.A. co-efficients of proprietary disinfectants, and we would suggest that the co-efficient be reported upon a 1% dilution instead of calculating to unity on the original preparation. In this event it will be necessary for the concentration of the active component to be stated on the label. Concentrated solutions are prepared merely for convenience of sale and transport as they are never used until diluted with considerable volumes of water, and as we have found, the co-efficients of the diluted preparations would be of greater value than that of the concentrated. Our work also shows that a much lower number is given by the dilution of a concentrated preparation than by the original preparation of a dilute disinfectant. It seems evident that a great waste of good material is thus taking place in the manufacture of the concentrated article.

Whilst engaged in the preparation of this paper we observed an article in "The Australasian Journal of Pharmacy," 20/1/1923, pages 35–37, on "Liquor eucalypti saponatus, etc.," by Messrs. B. L. Stanton and A. T. Sissons." The reason for their obtaining such poor results in the Rideal-Walker tests from the elegant preparations used was the high concentration of the Eucalyptus oils. If 1% solutions of these preparations had been made the co-efficients would have been more promising. In order to obtain comparable results, the concentrations of the preparations under examination should, in our opinion, be of the same order as the standard carbolic acid, 1%.

The confirmation of the observation of the effect of concentration or dilution upon the co-efficient was obtained by the following means:—Two preparations using the crude oil of *E. dives* made up with rosin in a similar manner to that of commercial practice of 38% and 57·5 % concentrations respectively gave co-efficients of 1·5 and 2 calculated as unity. Now the amount of crude oil in 5 c.c. of the standard 1% suspension required to give a co-efficient of 8 is 0·05 c.c., whereas in the case of Sample "A" (38% crude oil) suspension 0·019 c.c., the amount in 5 c.c., gave a co-efficient of only 1·5. This when brought up to 0·05 c.c. should give the same value as the standard 1%, *i.e.* 7: calculated (0·019 × 2·63) it gives a co-efficient of only 3·9. When the concentration is diluted to the standard 1% then 0·05 c.c. gives a co-efficient of only 3. Clearly this points to a considerable economic waste, maximum values being obtained by the use of initial high dilutions. In the case of Sample "B" (57·5% oil) suspension a co-efficient was obtained of 2, 0·0288 c.c. being the amount in 5 c.c. This when calculated to the standard 0·05 c.c. (0·0288 × 1·73) should give a co-efficient of 3·46, less than half. When the concentration is diluted to the standard 1%, then 0·05 c.c. gives a co-efficient of only 2. It will be seen that the loss is progressive, the greater the concentration of the disinfectant, the greater the loss in efficiency. Some commercial disinfectants contain over 50 per cent. of active constituents, especially those prepared from coal-tar oils, where the activity is due to carbolic acid and the mixed cresols. To increase the efficiency and prevent unnecessary waste it would be best for disinfectants to be standardised in their preparation. Optimum concentrations are necessary. Taking the standard 1% suspensions of the crude oils the table shows that *E. dives* is 7 to 8 times stronger than carbolic acid of the same strength.

As shown in Table "C," suspensions were also prepared with crude tar oil and pure carbolic acid for comparison. 1% concentrations when similarly prepared gave a co-efficient of 7, whilst a similar suspension of 16% concentration in the same strength of rosin soap gave a co-efficient of 0·6, that is when reduced to unity, *i.e.*, treated as an ordinary disinfectant. But a 1% dilution of the 16% tar oil suspension gave a co-efficient of 3, a reduction of less than half. Now the amount of tar oil of the 16% suspension (reduced to unity) in 5 c.c. to give a co-efficient of 0·6 is 0·008 c.c., calculated (0·008 × 6·25) should give a co-efficient of 3·75 (about one half). The concentration when reduced to the standard 1%, 0·05 c.c. gives a co-efficient of only 3. The 1% standard suspensions gradually increased in germicidal value. Our experiments show that the germicidal value of a disinfectant is dependent on the degree of the initial dispersion obtained, *i.e.*, the greater the dispersion the greater the germicidal efficiency. Proof of this contention was obtained by preparing a 10% concentration of the oil of *E. radiata (E. numerosa)* in 7½% rosin soap solution, and making a 1% dilution thereof using the soap dilution. This on testing gave the same co-efficient as the original standard 1%. Another dilution was made by using distilled water instead and the co-efficient determined, the result of which is shown in Table "C." Experiments were also conducted with concentrated suspensions of *E. dives* oil with similar results, which are given in same table.

Table "A."—*Commercial Eucalyptus Oils.*

Crude Oil.	Constants.	O.A. Coefficients.	Active Constituents.	
			Principal.	Minor.
E. polybractea	Sp. gr. $\frac{15}{15}$°C. 0·9288 Opt. rot. + 0·2° R.I. 20°C. 1·4605 Cineol 85%	5	Cineol	small amounts of the aromatic aldehydes
E. Australiana	Sp. gr. $\frac{15}{15}$°C. 0·9169 Opt. rot. +3° R.I. 20°C. 1·4635 Cineol 62%	5	Cineol	Terpineol Geraniol Citral
E. dives	Sp. gr. $\frac{15}{15}$°C. 0·9027 Opt. rot. - 62·5° R.I. 20°C. 1·4807 Piperitone 52%	8	Piperitone	Piperitol
E. radiata (*E. numerosa*) First sample)	Sp. gr. $\frac{15}{15}$°C. 0·8904 Opt. rot. - 34·64° R.I. 20°C. 1·4775 Ester No. 8·4 Piperitol 15% approx.	10	Piperitol	Piperitone
ditto (cultivated tree)	Sp. gr. $\frac{15}{15}$°C. 0·8884 Opt. rot. – 55·4° R.I. 20°C. 1·4772 Ester No. 56·69 Piperitol 20% approx.	12	do	do.
E. citriodora	Sp. gr. $\frac{15}{15}$°C. 0·8795 Opt. rot. + 0·65° R.I. 20°C. 1·4562 Citronellal 90%	8	Citronellal	
E. cneorifolia	Sp. gr. $\frac{15}{15}$°C. 0·9203 Opt. rot. - 6·8° R.I. 20°C. 1·4697 Cineol 50%	7·5	Cineol	Australol cymene aromatic aldehydes
E. phellandra First hour	Sp. gr. $\frac{15}{15}$°C. 0·8996 Opt. rot. - 13° R.I. 20°C. 1·4630 Cineol 50%	6	Cineol Terpineol	Piperitone ? Piperitol ?
E. Staigeriana	Sp. gr. $\frac{15}{15}$°C. 0·8822 Opt. rot. – 26·4° R.I. 20°C. 1·4797 Citral 38%	11	Citral	unidentified alcohol
E. Macarthuri	Sp. gr. $\frac{15}{15}$°C. 0·9255 Opt. rot. + 3·2° R.I. 20°C. 1·4692 Geranyl acetate 75%	1	...	Geraniol
E. hemiphloia (not at present commercial)	Sp. gr. $\frac{15}{15}$°C. 0·8902 Opt. rot. – 28·02 R.I. 20°C. 1·4883 Cineol trace only	7	Cymene aromatic aldehydes Australol	

Table "B."—*Pure constituents (freshly prepared) of Eucalyptus Oils.*

Constituent	Nature.	Source.	Constants.	Coefficient
Cymene	hydrocarbon	*E. lactea*	B.Pt 174½ – 175°C. (u.c.) at 764 mm. Sp. gr. $\frac{15}{15}$°C. 0·8635 inactive Ref. Index 20°C. 1·4878	8
Cineol	oxide	*E. polybractea*	M.Pt 1°C. Sp. gr. 0·930 R. I. 20°C. 1·4575	3·5
Pinene, l.a.	terpene	*E. phlebophylla*	B.Pt 155 – 156° C. at 764 mm. Sp. gr. 0·8617 Opt. rot. – 43° R.I. 20°C. 1·4655	1
Phellandrene	do.	*E. radiata (numerosa)*	B. Pt 59 – 60°C. at 10 mm. Sp. gr. 0·8475 Opt. rot. – 64·75° R.I. 20°C. 1·4763	2
Limonene	do.	*E. Staigeriana*	175 – 176° C. at 766 mm. Sp. gr. 0·8495 Opt. rot. – 75·75° R.I. 20° C. 1·4748	1
Aromandendrene	sesquiterpene	*E. nova-anglica*	B. Pt 124 – 125°C. at 10 mm. Sp. gr. 0·9222 Opt. rot +4·7° R.I. 20°C. 1·4964	under 1
Terpineol	alcohol	*E Australiana*	B. Pt 100 – 101°C. at 10 mm. Sp. gr. 0·9359 Opt. rot. – 5° R.I. 20°C. 1·4816	7·5
Geraniol	do.	ex geranyl acetate from *E. Macarthuri*	B. Pt 110 – 112°C. at 10 mm. Sp. gr. 0·8853 inactive R.I. 20°C. 1·4764	21
Piperitol	do.	*E. radiata (numerosa)*	B. Pt 95 – 96° C. at 10 mm. Sp. gr. 0·9283 Op. rot. – 34·1° R.I. 20°C. 1·4769	13

Table "B."—*continued.*

Constituent	Nature	Source	Constants	Coefficient
Eudesmol	sesquiterpene alcohol	*E Moorei*	M. Pt 79 – 80° C. Sp. rot. $[a]_D$ 20° C. + 35·5°	under 1
Geranyl acetate (85%)	ester	*E. Macarthuri*	Sp gr. $\frac{15}{15}$°C. 0·9168 Opt. rot. + 0·15° R.I. 20° C. 1·4660	none
Citral	aldehyde	*E. Staigeriana*	B. Pt 104 - 105° C. at 7 mm. Sp. gr. 0·8928 inact. R. I. 20°C. 1·4875	19·5
Citronellal	do.	*E. citriodora*	B. Pt 88 – 89° C. at 10 mm. Sp. gr. 0·8552 Opt. rot. + 1° R. I. 20°C. 1·4464	13·5
Cuminal	do.	*E. cneorifolia*	B. Pt 110° C. at 10 mm. Sp. gr. 0·982 inact. R. I. 20°C. 1·5287	12·75
Phellandral	do.	do.	B. Pt 90°C. (5 mm.) Sp. gr. 0·9440 Opt. rot. – 130·85° R. I. 20°C. 1·4912	9·25
Cryptal	do.	*E. cneorifolia* and *E. hemiphloia*	B. Pt 98 – 100° C. at 10 mm. Sp. gr. 0·9471 Opt. rot. – 60° to – 76·2° R. I. 20° C. 1·4826 to 1·4830	12
Isovaleric aldehyde	do.	*E. Macarthuri*	B. Pt 92·5° C. at 760 mm. Sp. gr. 0·8048 inact. R. I. 20° C. 1·3883	5
Piperitone	ketone	*E dives*	B. Pt. 108° C. at 10 mm. Sp. gr. 0·9381 Opt. rot. – 16·95° R. I. 20° C. 1·4839	8
Piperitone 90% (commercial)	do.	do.	Sp. gr. 0·9369 Opt. rot. – 42·2° R. I. 20° C. 1·4835	8
Australol	phenol	*E. cneorifolia*	M. Pt 62 – 63° C.	22·5

(All specific gravities were taken at $\frac{15}{15}$° C. R. I. is merely an abbreviation for refractive index.)

Table "C."

		C. A. Coefficient.
Crude oils made up with rosin and caustic soda solution as in commercial practice:—		
E. dives	38% concentration	1·5
do.	57·5 do.	2·0
do.	64 do.	1·5
E. Australiana	65 do	1·75
Concentrations in 7½% Rosin Soap solution:—		
E. numerosa	10% concentration (as unity)	0·5
do.	1% absolute diluted with 7½% rosin soap solution	11·5
do,	1% absolute, diluted with water	4·0
E. dives	5% concentration (as unity)	0·19
do.	1% absolute, diluted with 7½% rosin soap solution	7·0
do.	1% absolute, diluted with water	3·5
Crude Tar Oil :—		
	1% concentration	7·0
	16 do. (as unity)...	0·6
	16 do. (1% absolute, diluted with 7½% rosin soap solution)	7·0
	do. (1% absolute, diluted with water)	3·0
Pure Carbolic Acid:—		
	1% concentration	2·5
	16 do. (as unity) ..	0·25
	do. (1% absolute, diluted with water)	1·5

All values are calculated on the oil basis. Aqueous dilutions made with distilled water.

We have again to express our thanks to Mr. G. Hooper, F.T.C., Curator of the Technological Museum for enabling our co-operation, and to Dr. E. W. Ferguson, Principal Microbiologist, Department of Public Health, Sydney, for kind permission to carry out the bacteriological work in the Microbiological Laboratory, and to Mr. F. R. Morrison, Assistant Chemist, for much assistance in the chemical part of the paper.

STYPANDRA GLAUCA—A SUSPECTED POISON PLANT.

By MAX HENRY, M.R.C.V.S., B.V.Sc., and W. L. HINDMARSH,
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[*Read before the Royal Society of N. S. Wales, June 6, 1923.*]

THIS plant which is found on the coast, Blue Mountains, and in some of the wheat and sheep districts, has been reported as poisonous to stock especially during dry spells, when there is little other herbage. Reports from Western Australia state definitely that the plant is poisonous, but stockowners in this State are divided in opinion about it. To try and gain definite knowledge concerning *S. glauca*, experiments were carried out by the authors, as officers of the Stock Branch, Department of Agriculture.

Botanical Description.—The Government Botanist, Mr. J. H. Maiden, has kindly supplied the following botanical description:—

"*Stypandra glauca* R. Br., Prod. 279. A leafy perennial with stems on a creeping rhizome sometimes low and tufted, or weak and ascending, under 1 ft. high, sometimes 2 or 3 ft. high, woody and branched at the base. Leaves distichous, the sheaths usually concealing the stem, somewhat flattened with an acute keel, or almost terete, the blade erect or spreading, linear or lanceolate, usually 3 to 4 in. long, but sometimes twice that length and varying from 2 to 4 lines in breadth. Flowers in a loose terminal dichotomous cyme usually leafy at the base, the branches very spreading, the filiform pedicels recurved, varying from ½ to 1 in. long, mostly solitary but sometimes two together at the ends of the branches, without subtending bracts except sometimes a leafy one under the lowest. Perianth blue, often turning red in drying, the segments very acute, 5 nerved, about 6 lines long, stamens very much shorter; filaments filiform and twisted in the lower half, with a dense oblong tow-like tuft of hairs under the anther; anther shorter than the filament, much recurved, almost spiral after shedding the pollen, capsule oblong, 3 to 4 lines long. Seeds several in each cell, rather less flattened than in *S. cæspitosa*, smooth but not shining.—B.Fl., 2111, p. 53."

Reputed Poisonous effects:—

In the Agricultural Gazette, March 1894, p. 142, Mr. J. H. Maiden, Government Botanist, says:—

"Mr. Ash states:—'This is a herb which is stated to cause animals that have been fed on it to go apparently blind and run into any sort of object. It seems to be the least fatal of all the poison plants. *It is slower in taking effect.* This plant is common in the neighbourhood of Sydney, the Blue Mountains, and many other parts of the Colony, but I have never heard of it being reported as a poison plant here. But in Western Australia, it is much more abundant than it is with us, and it has so frequently and so consistently been reported as the cause of "Blind Disease," that there appears to be no room to doubt its poisonous nature.'"

In a reply to a query in August 1920, from the Stock Branch, the Chief Inspector of Stock of Western Australia supplied the following information:—

"Experiments have been tried on rats with material that was obtained from certain parts of the wheat belt of this State, portions of the plant being fed to the rats with the result that *blindness occurred on the second day, the whole ration being three grains.* In many cases sheep have been badly affected with blindness as a result of eating this plant. Horses also in the south-west portion of the State have not infrequently suffered from partial paralysis of the hind quarters when depasturing on country where the plant is fairly prevalent. Its effects seem to vary in different districts, but so far all tests up to the present have given positive results. The plant appears to be most injurious in the early winter and before other plants have become fully established."

Mr. Laverack, Grazier of Emmagool, N.S.W., stated, "I feel certain that stock feeding upon *Stypandra glauca* here in this district will not be affected with any symptoms of blindness."

Mr. Munro, Grazier of Oatombal, Cumnock, N.S. Wales, stated:—

> "I have a number of cattle and sheep poisoned and I blame this weed."

Mr. Munro also stated that the plant is rarely eaten by cattle except at drought times; that sheep were found dead within 24 hours of being placed in the paddock where *S. glauca* grew; that he was unable to definitely identify the plant in the ingesta of the dead sheep; that in cattle he suspected that symptoms of nervous irritability displayed by the cattle were caused by the ingestion of this plant; that at no time were his losses heavy; and that at times when driving sheep through the paddock where *S. glauca* grew, he noticed sheep to take a mouthful now and again without any harmful results. He further stated that when he rooted up all the Blue Bell in the paddocks deaths ceased.

In feeding experiments, the authors had great difficulty in most cases in inducing stock, and especially sheep, to eat the plant.

From the above reports it will be seen that *S. glauca* has been accused of producing:—

I. Blindness within forty-eight hours.
II. Partial paralysis of the hind quarters of horses.
III. Deaths in sheep within twenty-four hours.
IV. Symptoms of nervous irritability in cattle.

In June, 1920, experiments were initiated at Emmagool.

(*a*) Horse—aged gelding, light draught was fed 7½lbs. of chaffed plant sprayed with molasses. He refused to eat. He was then starved 24 hours and fed with the above mixed with three lbs of chaff. Within eight hours he had eaten all but 1½ lbs. He was then fed with 3 lbs. of chaffed plant but refused to eat until mixed with chaffed hay.

(*b*) Three other horses ate the unchaffed plant in ¼ lb. amounts readily.

(*c*) Sheep—aged merino ewe. Fed 3 lbs. of chaffed *S. glauca* sprayed with molasses. She refused to eat after starving twelve hours. She was then fed 1 lb. *S. glauca* by hand. Following this, she was fed on a mixture of chaff and *S. glauca*, gradually reducing the amount of chaff given.

(*d*) Two rams, merino and crossbred. Fed unchaffed *S. glauca*. They refused to eat although starved 48 hours.

(*e*) Cattle—One cow and a calf ate the unchaffed plant readily in ¼ lb. amounts.

(*f*) Kangaroo—A tame kangaroo ate the unchaffed plant readily in ¼ lb. amounts.

As it was not possible to personally carry out the work for more than two days, these feeding experiments were continued by Mr. Laverack who reported that he was unable to detect any ill results in the animals after feeding.

Experiments, December, 1920. Sheep penned on the farm and starved 48 hours before feeding.

Pen A. One merino and one crossbred. Although starved these sheep refused to eat *S. glauca*. They were then forcibly fed.

Dec.	7	2	ounces	(swallowed)	each
,,	8	4	,,	,,	,,
,,	9	5	,,	,,	,,
,,	10	5	,,	,,	,,
,,	11	6	,,	,,	,,
,,	12	5	,,	,,	,,

In all, 27 ounces were eaten in six days, an average of 4½ ounces daily. No ill effects were noted from ingesting these amounts.

Pen B. One merino and one crossbred.

Dec. 7 Fed *S. glauca* none eaten.
,, 8 Fed 4 ozs. *S. glauca* and ½ ℔. chaff. Possibly 1 oz. of ,, eaten.
,, 9 Fed 4 ozs. ,, and 2℔s. chaff and pollard, all eaten
,, 10 ,, 6 ,, ,, and ,, ,,
,, 11 ,, 8 ,, ,, ,, ,, ,,
,, 12 ,, 8 ,, ,, ,, ,, ,,

In all, 27 ounces were eaten in 6 days, an average of 4½ ounces daily. No ill effects were noted from the ingestion of the above amounts.

Pen C. One merino wether.

Dec. 7 Forcibly fed 1 ounce *S. glauca.*
,, 8 Drenched with 1 pint of decoction of 4 ℔s. *S. glauca* in 1½ gallons water, boiled two hours.
,, 9 Drenched with remainder of above decoction evaporated in water bath.

No ill effects noted.

Experiments, May 1921, (early winter). Sheep starved 48 hours.

Pen A. Two crossbred wethers.

May 9 Fed *S. glauca*, none eaten.
,, 10 ,, 4 ozs. *S. glauca* chaffed with 1 ℔. oaten chaff, all eaten.
,, 11 ,, 8 ,, ,, and chaff, 6 ozs. *S. glauca* eaten.
,, 12 ,, 8 ,, ,, ,, and pollard, all eaten.
,, 13 ,, 1 ℔. ,, ,, all eaten.
,, 14 ,, 6 ozs. ,, ,, all eaten.

In all, 40 ounces were eaten in six days by two sheep. No ill effects were noted from the ingestion of these amounts of *S. glauca*.

Pen B. Two sheep, merino and crossbred.

May 9 Fed 1 ℔. *S. glauca*, 4 ozs. eaten.
,, 10 ,, ,, ,, ,, ,,
,, 11 ,, ,, ,, ,, ,,

Crossbred forcibly fed as follows:—

May 12 2 ozs. *S. glauca*.
,, 13 4 ,, ,,
,, 14 2 ,, ,,

May 12, Merino drenched with extract of 5 ozs. spirit and 5 ozs. *S. glauca* (left 12 hours to extract), spirit evaporated. No ill effects were noted from the feeding and drenching in these sheep.

Pen C. One merino, starved 48 hours.

May 10 Drenched with ether extract of 5 ozs. *S. glauca* (24 hours, ether evaporated).
,, 12 Drenched with decoction of 1 ℔. *S. glauca* and two gallons water, evaporated to one pint. Sheep showed blackish diarrhœa for 24 hours after latter treatment but no other ill effects.

September 1921. Experiments with Guinea Pigs.

Guinea Pig No. I. Refused to eat *S. glauca* at all and died in cage.

Guinea Pigs No. II. and No. III.:—

	28/1/22.	29/8/21.	1/9/21.	2/9/21.	3/9/21.
No. II.	20 gr.	30 gr.	20 gr.	30 gr.	20 gr.
,, III.	20 gr.	...	10 gr.	10 gr.	...

These guinea pigs were fed by hand as they refused to eat the plant otherwise. They had in addition a small ration of grass. No ill effects were noted as a result of the ingestion of *S. glauca*.

Guinea Pig No. II. given 1 oz. of decoction of 8 oz. *S. glauca* in one quart of water. Two days later given extract made of 2 ozs. of *S. glauca* in 4 ozs. spirit, 48 hours, evaporated to ½ oz. No ill effects were noted.

Guinea Pig No. III. given extract of 2 ozs. *S. glauca* in 4 ozs. ether, (4 days), evaporated to paste. No ill effects were noted.

January 1923. A cow was fed and ate 15 lbs. of chaffed *S. glauca* with an equal quantity of hay and a little molasses, in three days, without ill effects.

These experiments were all short and in order to test the effect of long continued feeding, arrangements were made with Mr. R. A. Patten, B.V.Sc., the Manager of Bangaroo Stud Farm, for a supply of material, sheep and facilities for carrying out the required experiments. The services of Mr. A. McKay, Veterinary Student at the University of Sydney were also obtained in connection with the actual feeding.

The sheep selected for the experiment were two tooth black merino ewes, and on 29/12/22, they were brought into the yards, shelters were erected and the pens in which they were to be confined cleared of all vegetation. Until 1/1/23, they were all fed alike on hay. A little *Stypandra glauca* was thrown in and six of those which ate it most readily were selected and placed in pen A. Two others were then placed in each of pens B, C, and D. The plant was cut fresh daily.

The sheep in pen A were fed entirely on *S. glauca*, those in B on a mixture of *S. glauca* and hay, the proportion of hay being gradually decreased. In pen C, the sheep were fed on hay, but were drenched with the fluid obtained by soaking the plant in water for some hours and extracting with a modified yeast press. In pen D were kept the controls fed on hay alone.

All received water from the same source. The details of the quantities eaten are as follows:—

PEN A—Fed on *Stypandra glauca* only.
Date put into pen—29th December, 1922.
Date *S. glauca* started—1st January, 1923.

Date.	Amount *S. glauca* fed	Amount Remaining.	Consumed.	Remarks.
Jan. 1	6 lbs.	1 lb.	5 lbs.	Hay and *S. glauca* fed.
,, 2	6 ,,	2½ ,,	3½ ,,	
,, 3	6 ,,	3¾ ,,	2¼ ,,	
,, 4	6 ,,	4 ,,	2 ,,	
,, 5	6 ,,	5 ,,	1 ,,	
,, 6	4 ,,	2¼ ,,	1¾ ,,	
,, 7	4 ,,	2 ,,	2 ,,	
,, 8	4 ,,	2¼ ,,	1¾ ,,	
,, 9	4 ,,	2 ,,	2 ,,	
,, 10	4 ,,	2 ,,	2 ,,	
,, 11	4 ,,	2 ,,	2 ,,	
,, 12	4 ,,	2 ,,	2 ,,	
,, 13	5 ,,	2½ ,,	2½ ,,	
,, 14	5 ,,	2½ ,,	2½ ,,	
,, 15	5 ,,	1½ ,,	3½ ,,	
,, 16	6 ,,	2½ ,,	3½ ,,	(All sheep drenched with *S. glauca* extract.)
,, 17	7 ,,	2 ,,	5 ,,	Major portion consumed was stalks.
,, 18	8 ,,	2 ,,	6 ,,	
,, 19	8 ,,	2½ ,,	5½ ,,	
,, 20	8 ,,	3 ,,	5 ,,	
,, 21	8 ,,	1¼ ,,	6¾ ,,	
,, 22	8 ,,	2 ,,	6 ,,	
,, 23	8 ,,	1½ ,,	6½ ,,	
,, 24	10 ,,	2 ,,	8 ,,	
,, 25	10 ,,	2¾ ,,	7¼ ,,	
,, 26	10 ,,	2 ,,	8 ,,	
,, 27	10 ,,	1 ,,	9 ,,	
,, 28	12½ ,,	½ ,,	12 ,,	Very young *S. glauca* fed

Pen B.—Fed on mixed hay and *Stypandra glauca* (chaffed).

Date put into pen—29th December, 1922.

Date *S. glauca* started—1st January, 1923.

Date.	Amount mixt fed.	Amount remaining	Consumed	Remarks
Jan. 1	3 ℔s.	2 ℔s	1 ℔	
,, 2	3 ,,	2½ ,,	½ ,,	
,, 3	4 ,,	3½ ,,	½ ,,	
,, 4	4 ,,	3¼ ,,	¾ ,,	
,, 5	4 ,,	3¼ ,,	¾ ,,	
,, 6	4 ,,	2 ,,	2 ,,	
,, 7	4 ,,	1 ,,	3 ,,	Proportion of hay to *S glauca* was 1 : 1
,, 8	4 ,,	1 ,	3 ,,	
,, 9	4 ,,	1 ,,	3 ,,	
,, 10	4 ,,	¾ ,,	3¼ ,,	
,, 11	4 ,,	1½ ,,	2½ ,,	
,, 12	5 ,,	1 ,,	4 ,,	
,, 13	5 ,,	1 ,,	4 ,,	
,, 14	5 ,,	1 ,,	4 ,,	,, ,, 2 : 3
,, 15	5½ ,,	½ ,,	5 ,,	,, ,, 2 : 3½
,, 16	6 ,,	1 ,,	5 ,,	,, ,, 2 : 4
,, 17	6 ,,	½ ,,	5½ ,,	
,, 18	6 ,,	¼ ,,	5¾ ,,	,, ,, 1½ : 4½
,, 19	6 ,,	¼ ,,	5¾ ,,	
,, 20	6 ,,	½ ,,	5½ ,,	,, ,, 1 : 6
,, 21	7 ,,	1¾ ,,	5¼ ,,	
,, 22	7½ ,,	1¾ ,,	5¾ ,,	,, ,, 1½ : 6
,, 23	8 ,,	1¾ ,,	6¼ ,,	,, ,, 2 : 6
,, 24	8 ,,	2 ,,	6 ,,	
,, 25	8 ,,	3¼ ,,	4¾ ,,	
,, 26	7 ,,	3 ,,	4 ,,	,, ,, 1 : 6
,, 27	7 ,,	½ ,,	6½ ,,	
,, 28	8 ,,	¾ ,,	7¼ ,,	,, ,, 1 : 7

Pen C.—Fed on hay and drenched.

Date put in pen—29th December, 1922.

Date drenching started—4th January, 1923.

Date.	Amount used to make Drench.
January 4 to 17,	½ ℔, *S. glauca* to make 4 fluid oz per day.
,, 18 to 29,	1 ℔. ,, ,, 4 ,,

Amount of hay fed to each of Pens C and D. (Pen D. are controls).

Date.		Amount hay fed.	Amount remaining.	Consumed.
January	4	3½ lbs.	1¾ lbs.	1¾ lbs.
,,	5	3½ ,,	1 ,,	2½ ,,
,,	6	3 ,,	¼ ,,	2¾ ,,
,,	7	3 ,,	. .	3 ,,
,,	8	3½ ,,	...	3½ ,,
,,	9	4 ,,	...	4 ,,
,,	10	4½ ,,	½ ,,	4 ,,
,,	11 to 28	4 ,,	2 ,,	2 ,,

Pen.	No. of Sheep.	Total amount consumed.*	Amount per head consumed.	Amount per head per day consumed.
A.	6	118 lbs. of *S. glauca*	19·6 lb.	·7 lbs.
B.	2	112 lbs mixture	56 ,,	2·0 ,,
C. } D. }	2	90 ,, hay	45 ,,	1·8 ,,

* Amount of hay fed with *S. glauca* from 1st to 3rd was substracted.

No untoward symptoms of any kind were detected either during the experiment or after its completion.

Summary of Feeding Experiments.

Stypandra glauca has been fed to live stock to test its reputed poisonous properties.

The plant was fed to animals of five species, viz., horses, cattle, sheep, guinea pigs, and kangaroo.

The number of individual animals experimented with was 32, made up of 4 horses, 2 cows, 1 calf, 22 sheep, 2 guinea pigs, and 1 kangaroo.

Experiments were carried out in five different months, January, May, June, September and December, and were spread over three years. Material was obtained from three districts all of which, however, were on the western slopes.

The longest period over which animals were fed exclusively on *S. glauca*, was 25 days. The largest quantity eaten in a short period was 14 lbs. consumed in 3 days by a cow.

In no instance were any symptoms of poisoning shown.

Fodder value of S. glauca.

With a view of ascertaining whether the plant might have any value in drought time if used as bulk fodder with concentrates, the Departmental Chemist, Mr. F. B. Guthrie carried out an analysis, the results of which were:—

Moisture, etc.	27·90	per cent.
Ash	2·92	„
Fibre	40·37	„
Ether Extract (Fat etc.)	3·17	„
Albumenoids	9·25	„
Carbohydrates	16·39	„

Obviously, its feeding value could hardly be regarded as high, owing to the large fibre content, but the experiment with Pen "A" at Bangaroo, showed that even when eaten as a sole diet in small amounts, it maintained animals in normal health although condition was lost. It may be pointed out that loss of condition would have accompanied the feeding with any plant in similar quantities.

Criticism of Conflicting Reports.

It may be permissible to offer some criticism of the Western Australian reports even though full details of the work done are not available. Unless stock are urged by hunger they will not, with some exceptions, eat this plant freely. Now under conditions of drought, many very indigestible and innutritious plants are consumed by stock and cases of visual disturbance are very common in animals which have for a long period been so fed. It does not require the presence of any particular plant in the feed to produce this condition. Pregnant ewes are most frequently affected. For the amaurosis reported to have resulted on feeding the plant to rats, we have no explanation to suggest.

In conclusion, we are unable to find any evidence that *Stypandra glauca*, as found growing in this State is harmful to live stock, but rather that the plant will support life for comparatively extended periods.

RELATIONSHIP OF THE AUSTRALIAN LANGUAGES.

By Professor A. L. KROEBER.

(Communicated by C. HEDLEY.)

[With Plates II - IX and Text Figures.]

[*Read before the Royal Society of N. S. Wales, June 6, 1923.*]

IN 1903 I began a study of the relations of the Australian languages among themselves, primarily with a view to the question of their genetic unity. In this work I was assisted for nearly a year by Mr. C. H. Marks, Jr. The larger part of all the lexical data available being assembled in E. M. Curr's Australian Race,[1] the study was based on this work, supplemented by some twenty vocabularies published subsequently,[2] which contributed information on a number of important areas which Curr was forced to pass over in silence. The plan followed was this. The native terms for a number of fundamental concepts, chiefly nouns and mostly such as denoted body parts, were transcribed as well as might be into a standardized orthography. This procedure of course introduced an element of conjecture but seemed unavoidable in view of the phonetic inadequacy and diversity of the orthography in which most Australian vocabularies have been rendered. Forms which were patently similar were then reckoned as going back to a common origin, without any endeavour to explain differences through sound shifts or on the basis of a refined analysis of the original recorder's peculiarities of transcription. This was a summary method: but the undertaking was a pioneer one, in which an over-accurate technique would have been sterile. All the occurrences of a single stem and its variants were then plotted on a map. At first the several fundamental stems for one concept, such as "eye," were represented by different colours on one map. It was soon found that for most concepts the distribution of stems was so irregular, and their number so great, that such maps yielded no very clear picture. The data for each concept were therefore entered on several maps, each of which showed the distribution of a single stem, or three, four, or five stems if the geographical range of these was comparatively narrow. A selection from these plots (maps 1–48) is the basis of the discussions in the present paper.

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[1] Four volumes, Melbourne and London, 1886-87.

[2] See Fig. 3 and list of works supplementary to Curr, below.

This method suffers, from a precise philological standpoint, through brushing over all finer detail. It cannot therefore be free from errors. In compensation, however, it should yield a perspective which with finer technique would be obtainable only through an almost lifelong preoccupation with the subject. The plan also has this merit: if a stem occurs in all parts of the continent, even though it may be lacking from this or that individual dialect, the fact is driven home forcibly by the map. If on the other hand it is widely spread but wholly lacking from a certain area, or if, *vice versa*, it occurs only in a certain area, these tracts are made to stand out vividly. In this way it was hoped that if there proved to be among the languages of the continent several stocks of distinct origin, or that if a single family had become diversified into several well differentiated branches, these facts would be revealed with convincingness. Some salient conclusions, at any rate, might be drawn; and preliminary as these might be, they would nevertheless furnish guidance in the chaos which has characterized Australian linguistics.

For years other duties prevented prosecution of the work, to which I was able to come back only from time to time.

Schmidt's Studies and Conclusions.

In 1908 Father W. Schmidt published a preliminary classification of the languages of Australia.[1] In 1912 he began in *Anthropos* an intensive study, the results of which appeared for a number of years. These articles in turn he revised and issued in book form in 1919.[2] Schmidt's studies have been much more laborious and intensive than mine. He arrives at conclusions somewhat different from those which I had formulated. These conclusions seem to me to be at least in part the result of his method of interpretation.

Our methods of attack are the same, except that he has been more painstaking and has concerned himself with a much larger number of words, besides having included certain materials which the suspension of my work a number of years ago caused me not to reach. Schmidt reproduces the most important portions of his data in standardized orthography, and classifies the almost numberless dialects into groups. Up to this point there is no question that his procedure is more exhaustive than my rather cursory one. When, however, it comes to interpretation, Schmidt largely abandons the natural method of linguistic comparison, which regards similarities as *prima facie* evidence of genetic relationship, and sufficient dissimilarity as proof or at least presumption of lack of common origin. Instead, he has thrown himself into the arms of the "culture history method" of Graebner—a theory which holds that there have occurred several distinct populational and cultural migrations into Australia. Schmidt analyzes his material to find evidence of these successive strata, each of which is supposed to have brought with it one or more languages. He thus intermingles analysis of present phenomena with synthesis of hypothetical former ones, instead of proceeding viâ an analysis of existing conditions to a comprehensive synthetic understanding of them, and only then evolving inferences as to the past. In short, he partly explains the known present by the unknown past; which is also the method of Graebner's ethnology.

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[1] Man, VIII, p. 184.

[2] Die Gliederung der Australischen Sprachen, Wien, 1919.

The result is that Schmidt often finds in a given language remnants of several stocks that no longer exist, and traces the borrowings and mixtures of constituents which we do not know as such and which he has scarcely begun to substantiate. Another consequence is that he touches the problem of genetic relationship only obliquely. He does maintain that the languages of the larger southern portion of the continent are related and that those of the smaller northern area are distinct, not only from the southern family but also among themselves. Since however most of the southern languages are the product of varying degrees of admixture from three or four migrations, each of which brought its own distinct culture and speech, the relationship that Schmidt admits for these southern languages is evidently not of the kind which is usually understood by philological relationship: namely, a common origin with subsequent diversification.

While this peculiar method of interpretation runs through Schmidt's work, it fortunately has not prevented him from establishing classifications on the basis of modern conditions. His coloured map summarizes these admirably. In other words, he is much too able a linguist to allow himself to fall completely under the sway of a historical theory. He does however considerably interweave his survey classification of the existing data with his hypothetical reconstruction.

This circumstance has led me to reassemble and formulate my own findings after having laid them aside for a number of years under the impression that they had been superseded by Schmidt's work. However rough my technique has been, I believe I have at least approached the material objectively and without theoretic preconceptions. Wherever my findings agree with Schmidt's they will therefore tend to rescue his from the cloud of hypothesis which hangs over his work. Where we differ, doubt will be more definitely established and renewed investigation stimulated.

Evidences of Continental Unity.

The first inference which the mappings seem to allow is that Schmidt's fundamental separation of the north and south Australian languages is unnecessary. He has indicated this demarcation by a red line running across the map of the continent from latitude 17° on the east coast to 19° on the west,[1] with a great southward indentation to latitude 28° in the centre to include the Arunta, and a few of the tribes on their northeast, with the northern group. This line has this validity: speech to the south of it is obviously much more homogeneous than on the north. In the northern division even adjacent languages often differ profoundly. Why this is so, remains to be determined. It probably cannot be ascertained until information on the northern languages is a great deal fuller than at present.

Nevertheless stem after stem is found with the same meaning on both sides of the line. The majority of the plottings show such a distribution. In nearly a third of the cases the double occurrence is decisive. That is, a stem appears not only on both sides of the line but in practically every portion of both northern and southern Australia. Maps 1, 7, 11, 13, 15, 17, 19, 25, 28, 37, 40 illustrate this condition.

It is not maintained that every stem plotted in these maps occurs in every single north Australian dialect. In so definitely established a family as Indo-European a stem has frequently disappeared from a whole division, or within a division from a language. Positive cases count much more heavily than negative ones in problems of this sort. The preponderance of weight which must be assigned to them is greater in proportion as the languages are imperfectly known. If all the knowledge we possessed of two such closely related languages as English and German lay in a few vocabularies recorded by travellers or non-philological residents, we should have to rate the words *dog* and *hund* as dissimilar stems for the same simple concept because we should not know that each recurred in the other language with the special meaning of *dogge* and *hound.* If ever we come to have a fourth as much knowledge of the Australian languages as of the European ones, it may begin to be time to lay weight on missing stems. Until then a comparatively small number of positive similarities will go far in establishing a presumption of genetic relationship.

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[1] In the 1919 reissue, a corrigendum to the map makes the line begin at latitude 15° on the east coast, so as to include Koko-Yimidir in the southern division.

To the foregoing may be added a number of further resemblances which are less widely distributed, but which involve stems that appear at least in several districts of both northern and southern Australia. These are plotted in maps 2, 4, 5, 6, 8, 12, 16, 21, 27, 29, 31, 32, 34, 37, 38, 39, 46, 47.

Admitting that the method used is somewhat in the nature of a reconnaissance, we must nevertheless conclude, it would seem, that the indications warrant a belief in the genetic unity of all the Australian languages.

Grouping of the Southern Languages.

When now the branches or subdivisions of this family are examined, it appears that the dialects of certain areas form much more consistent units than others. One of these units which began to stand out from the beginning of my comparisons and plottings is the Narrinyeri of the lower Murray.

Maps 5, 12, 14, 22, 27, 32, 45, 48, show this as a more or less isolated area.

The same holds of Schmidt's Darling group, upstream from the last, as revealed by maps 10, 14, 22, 27, 35, 44, 46 and in a less striking degree by several others.

A third though somewhat less distinctive group is that in Victoria adjoining the two last on the south: see maps 24, 36, 42, 43.

Schmidt's Yungar in the extreme south-west of the continent forms a well marked unit which stands out with but little variation of limits in maps 6, 8, 19, 25, 34, 45.

As regards the entity and boundaries of these four branches, my survey thus corroborates Schmidt's findings exactly. On the whole it also confirms his great North Central and South Central groups, which embrace the region between two lines, one stretching between the mouths of the Murray and Mackenzie, the other between latitude 17° on the east coast and longitude 134° on the south coast. The North Central group especially, which embraces the heart of Queensland, I had early noted as a solid unit. It shows thus in maps 2, 4, 5, 14, 22, 31, 36, 40, 44, 47, 48. The limits are not so precise as in the foregoing units, but this is a probable expectation for a larger area. The South Central group is considerably less defined on my maps. It appears as an area of moderate coherence nearly enclosed by the compact Narrinyeri, Darling, North Central, and Arunta groups. I should strongly incline to detach the Darling group from it.

Schmidt's large South-west has only the degree of coherence which so vast a tract, and that marginal to a core of desert, might be expected to possess. As a unit, inclusive or exclusive of Yungar, it is far from impressive on my maps. Still, maps 2, 6, 20, 21, 26, 31, 40 suggest its probable reality. Several of these cases are negative—that is, a widely spread stem is lacking for all parts of the Southwest.

Schmidt's Yuin-Kuri group of the New South Wales coast does not give me the impression of being a true distinctive unit. The same seems to apply to his Wakka-Kabi group, north and north-west of Brisbane. I should incline to connect the inland Wakka with the adjacent North Central division, Kabi with the other coast languages. In fact the East Coast languages from 37° to 17°, or even beyond, seem to constitute a natural unit.

This leaves, in southern Australia, Schmidt's Wiradhuri-Kamilaroi of interior New South Wales as the only division of any size unaccounted for. I find it difficult to do anything with the languages of this area. Schmidt looks upon them as a mixture of three of his strata, which remain best represented in the Yuin-Kuri, East Coast, and Central divisions respectively. Translated into objective terms, this means that the Wiradhuri-Kamilaroi languages are difficult to separate from all of their neighbours. On this point of agreement we can rest. Schmidt may be right in his view that modern Wiradhuri-Kamilaroi is the result of an ancient mixture: he certainly has not proved it.

This gives, for southern Australia, the following groups, in approximate order of the positiveness of their distinctiveness: Narrinyeri; Darling; Yungar; Victoria; North Central; East Coast; South Central; South-west; Wiradhuri-Kamilaroi. (See Fig. 1).

Grouping of the Northern Languages.

For northern Australia the data are much scantier and the local diversity is usually greater, so that a classification of any pretensions to permanent validity would be premature. Schmidt's grouping seems a conveniently formal rather than a natural one and can therefore scarcely be historically founded. He distinguishes languages that end in (1)

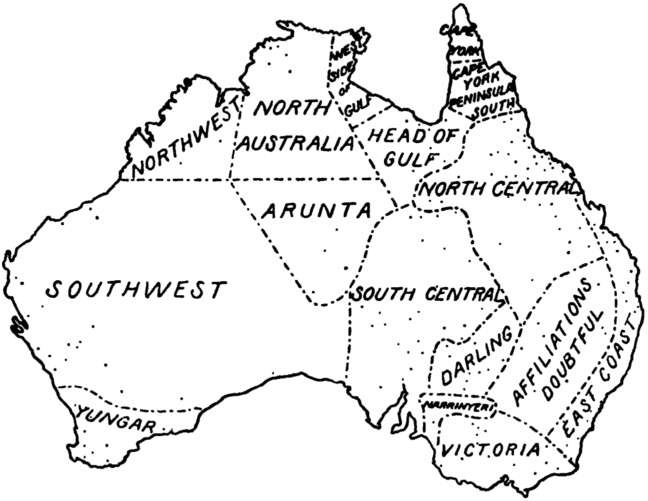
CAPE YORK
WEST SIDE OF GULF
CAPE YORK PENINSULA SOUTH
NORTHWEST
NORTH AUSTRALIA
HEAD OF GULF
NORTH CENTRAL
ARUNTA
SOUTHWEST
SOUTH CENTRAL
DARLING
AFFILIATIONS DOUBTFUL
EAST COAST
NARRINYERI
YUNGAR
VICTORIA

Fig. 1. The principal divisions of the Australian family of languages, revised from Schmidt's classification.

consonants, (2) sonants, (3) vowels, but these are geographically scattered. My distribution maps reveal several areas in which speech is comparatively uniform or at least sharply marked off from adjacent areas. One is the region of the Arunta, in which initial consonants have frequently been lost.[1] Another is the tip of Cape York peninsula, whose group of dialects is on the whole the most separate of any in Australia. In fact, a conservative attitude must leave it somewhat questionable whether they are part of the Australian family at all. A third rather uniform area extends south from the head of the Gulf of Carpentaria to the North Central group. This is the tract which Schmidt considers as having been the focus of meeting of the north and south Australian languages, and has designated by a sort of swelling of his red line of demarcation.

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[1] Eye, al-kna *ex* mil; ear, ilpo-kita *ex* talpa; teeth, ardita *ex* karditi; tongue, aliuya *ex* taling; beard, ongi-nya, arni-ngya *ex* naka; foot, ini-ga, in-ga *ex* tina; blood, irkna *ex* kuna; bone, onguna *ex* kungun; excrement, udna *ex* kuna, kudna; black man, urlu-, arila *ex* karu; fire, ura *ex* kun-. Similar "apocopes" are fairly numerous in dialects 53, 58 – 60, 61 – 65, 93 (Curr's numbers) and are encountered elsewhere.

For the rest, northern Australia is probably best divided provisionally into geographical tracts, without much insistence on the inner similarity of their languages. Of such tracts we may recognize:—

(1) The district of King Sound and Ord River, with fairly uniform speech as Schmidt shows. This might be called the North-west district.

(2) The coast from longitude 130°–135°, and thence south to include the Chingalee. The dialects here are remarkably diverse.

(3) The west coast of the Gulf of Carpentaria. The languages of this stretch may prove to belong with those of the adjoining divisions.

(4) Cape York peninsula between latitude 17° and 13° or 14°.

With the Arunta, head of the Gulf, and Cape York groups, this makes seven tentative areas in the north. (See Fig. 1.)

Differentiation of the Groups.

These groups of the south and north may be compared to test the relationship which I find to exist between the two divisions. I give the results in three columns. The first shows how many of the 11 stems plotted in maps 1, 7, 11, 13, 15, 17, 19, 25, 28, 30, 40 occur in each group, as represented by one or more or all of its dialects. Each of these stems appears in a majority of the southern and in a majority of the northern groups. The second column gives similar figures for 22 other stems each of which occurs in at least two southern and two northern groups. The distribution of these is shown in maps 2 (*bis*), 3, 4, 5 (*bis*), 6 (*bis*), 8, 12, 16, 21, 27, 29, 31, 32, 34, 37, 38, 39, 46, 47. The third column combines the figures for the first and the second.

	11 most widely distributed stems.	22 widely distributed stems.	Total for 33 stems.
North-west	10	5	15
130° - 135°	9	13	22
West Side of Gulf	7	5	12
Arunta	9	4	13
Head of Gulf	10	15	25
Cape York Peninsula South	8	12	20
Cape York	3	5	8
Yungar	7	6	13
South-west	10	11	21
North Central	11	17	28
South Central	10	12	22
Darling	6	5	11
Narrinyeri	8	9	17
Victoria	10	8	18
East Coast	11	13	24

A certain allowance must be made on account of the number of dialects in a group or the number of vocabularies available from it. Thus the low figure for the group on the west side of the Gulf of Carpentaria is probably to be laid to my having had but three word lists from this tract as against eight or ten from each of the adjacent districts. With an equal volume of material, it seems likely that this group would align at least as closely as the one on its west with the remainder of the continent. In part, too, but probably only in part, the low figures for the Darling and Narrinyeri groups can be attributed to their small area as compared for instance with the North and South Central districts. A vast tract of many tribes each with its dialect is more likely to preserve an ancient stem with its original meaning somewhere in its area than is a little district, which will tend to preserve or lose it as a unit.

Still, some inferences obtrude. There is no group that stands wholly aloof. The most divergent from all the others is unquestionably that of Cape York. The next most specialized in the north, considering its size and central location, is the Arunta. The northern group which has easily the most numerous southern resemblances is that at the head of the Gulf of Carpentaria; which is in accord with Schmidt's findings. In the south, the North Central, East Coast, and South-west evince, in the probable order named, the greatest affinity to the north. Yungar suggests considerable specialization, as might be expected from its restriction and marginal remoteness; Victoria and Narrinyeri less than might be anticipated. The figure for Narrinyeri is in fact rather high, considering the small area of the group. Darling, on the other hand, considering that it lies more northerly than Narrinyeri and in contact with more other groups, ranks surprisingly low. This then would seem to be a more distinct group than Schmidt has recognized it to be. We are of course dealing here with a very limited number of stems, which may prove not to be wholly representative of the vocabulary as a whole. But there is no reason to suppose that they happen to be thoroughly unrepresentative; and some presumption must therefore remain that the Darling group is well specialized.

A Typical Case: Water.

Fig. 2, which shows the principal forms of the words meaning water, seems to me to epitomize the linguistic situation in Australia. Disregarding isolated stems, we have about 200 sources giving us obviously comparable forms for this idea. These 200 words fall into about eight classes, according to their form. Thus words like wara, wala, wade, form one class, which is indicated on the map by the figure "8." Now the distribution of this type of stem ranges from the North-west to Head of the Gulf to Wiradhuri-Kamilaroi to Victoria. Stems of several of the other types are as widely and randomly distributed. Either then (assuming the eight word types to be radically dissimilar) we are dealing with a number of different families

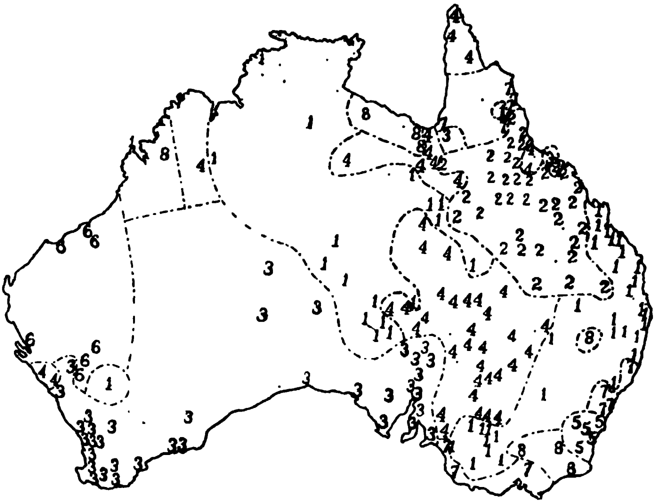
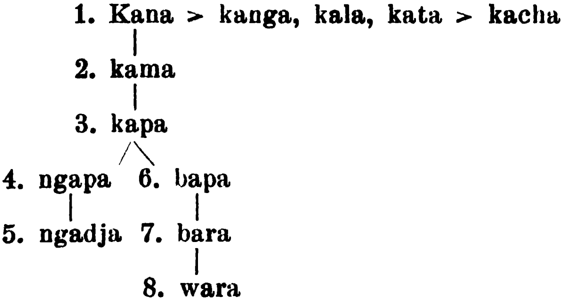


Fig. 2. Distribution of stems meaning water: 1 **kata**, **kala**, **kana**; 2 kama; 3 kapa; 4 ngapa; 5 ngadjung; 6 bapa: 7 bara; 8 wara.

which however have become geographically interspersed and blended, as Schmidt holds; or we have only one family in which separate stems, comparable to "water," "liquid," "moisture," "sap," have come, one here and one there, to take on the meaning of "water." In either event, the distribution does not follow the lines of dialect grouping accepted by Schmidt and myself. This fact shows that these groups must not be regarded as very deeply differentiated, and emphasizes the connections that exist between them.

But our eight word types evince enough similarity and transitional forms to support a tolerable case for the belief that they are at bottom *nothing but variants of a single* stem. Let us begin with number 3, which appears as kapi, gaba, kowi, kowara, and may be reduced to a schematized kapa. Type 2, kumum, kamu, kam, komo—schematic kama

—differs only in replacing the labial stop by a labial nasal. This brings us to type 1: kun, kong, kali, kalan, katini, kucha, kwacha, etc. These forms might have arisen from m altering to n, which in turn gave rise to ng, l, t, and the latter to ch. The remaining types differ from the preceding ones in that initial k is replaced. Class 4, for instance, comprises ngapa, napa, ngoko, noko, muku; that is, the initial palatal stop is altered to the palatal nasal, which in turn sometimes becomes dental or labial; whereas the medial or final consonant sometimes changes from labial to palatal stop. Type 5, ngadyung, differs from the last but slightly, ng-dy against ng-k. It also connects with type 1 in its forms kucha, katini. Another variant from our starting point kapa is furnished by type 6, bapa. This in turn leads to type 7 bari or pari; and from this there is no great step to 8, wara.



It may be added that types 2, 3, 4, 5 all appear occasionally without initial consonant: thus amu, awi, uku, idyong.

Now there is certainly no proof of the original identity of these eight type forms. It would be mere guessing to assert which one was original. The involved sound shifts, such as p > m > n > ng and k > ng and k > b > w, while authenticated in other languages, are as yet undemonstrated as at all general between the particular Australian dialects involved. And the vowels have been handled here in the most drastically schematic fashion. By the ordinary standards of philology, nothing more than a suggestion has been provided. But there neither exists the quality of material nor has it been subjected to an intensive enough analysis to apply to-day the standard of accuracy exacted in Indo-European and Semitic philology. In view of this present limitation on possible proof, I cannot but entertain a feeling of considerable probability that all these eight types of forms, and consequently all but a scattered and inconsistent minority of Australian words for water, go back to a common origin. At any rate, this seems a more simple inference than to explain these forms as due to a mixing of several stems that once were radically different because separate in origin.

Very similar conditions, I believe, will be found to exist in the case of other stems, as soon as these are brought together in a purely empirical manner. A positive assertion of genetic relationship, then, would still be premature to-day; but its likelihood seems strong. It will undoubtedly be wisest to suspend judgment until the evidence is sifted more analytically. Yet if an opinion is to be rendered now, it does appear that the assumption of the genetic unity of all the Australian languages is a safer one to make than the assumption that they are derived from several origins.

Curr's Classification.

Something should be said as to Curr, the pioneer in this field, whose compilation Schmidt and I have used so largely.

Curr's classification is not really a linguistic one. In spite of his three volumes of vocabularies, he institutes specific comparisons only between a few words in several dialects. What Curr appears actually to have done was to plot the distribution of circumcision and subincision. The Central area or division in which these practices are found gave him by exclusion his Western and Eastern areas. For some reason his "Darling tribes" (inside the broken red line on his map) are included in the Central division although they do not circumcise. This exception appears to be made on account of a native myth that this group of tribes is descended from a single male immigrant. Although coming from a Central group, this man would have no motive for mutilating his own sons, Curr reasons, so they never learned the customs which distinguish the other Central tribes!

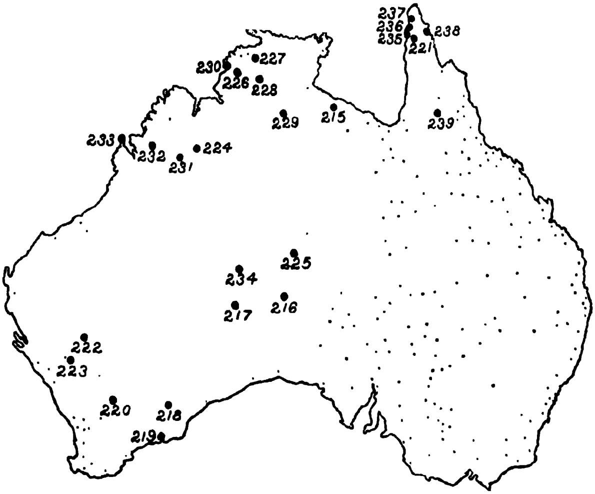
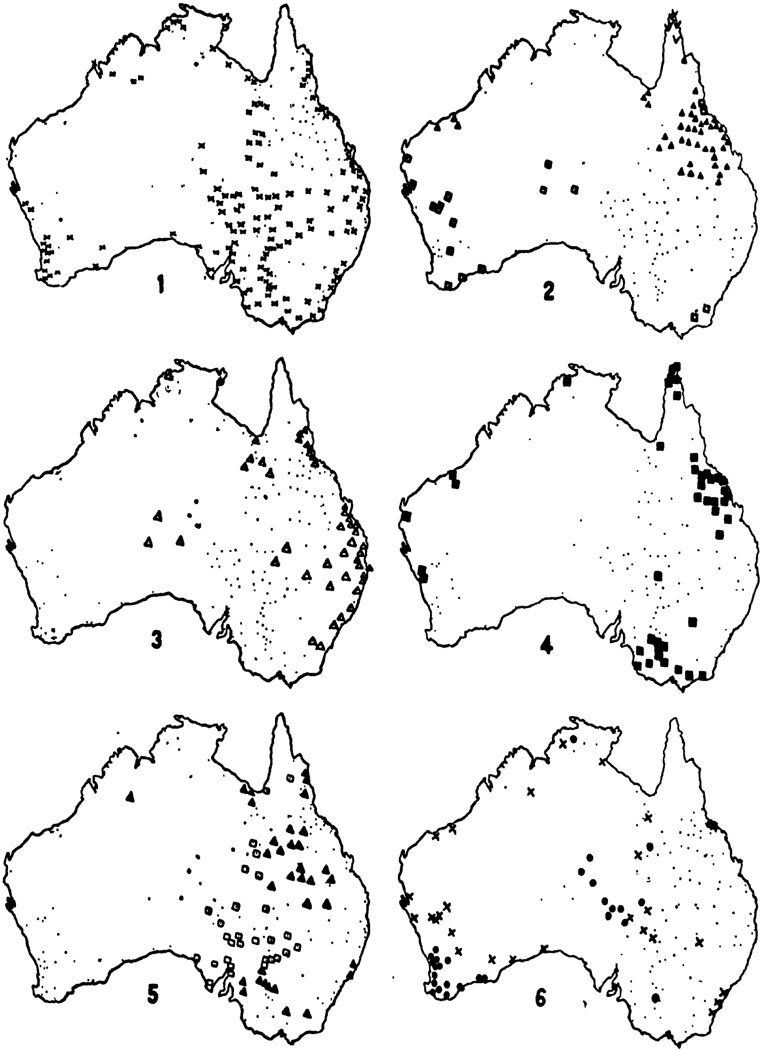


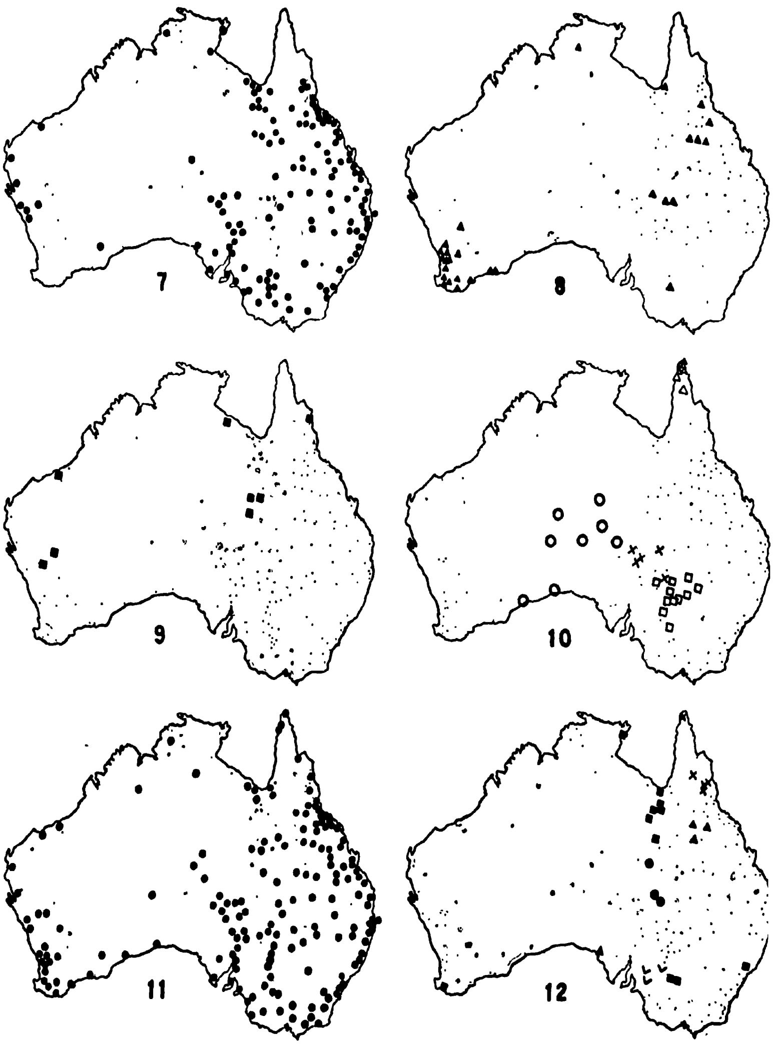
Fig. 3. Dialects from which vocabularies were used that are not in Curr's work.

Curr's Western division includes and excludes parts of Schmidt's and my Yungar and South-western groups. His Central Division lumps into one Northern Australia, Head of Gulf, South Central, Darling, Narrinyeri, Arunta, and most of the South-west. His Eastern division includes Cape York, Cape York South, North Central, East Coast, Wiradhuri-Kamilaroi, and Victoria. His classification is therefore not so much actually incorrect as superficial. His line between the Central and Eastern divisions is every-



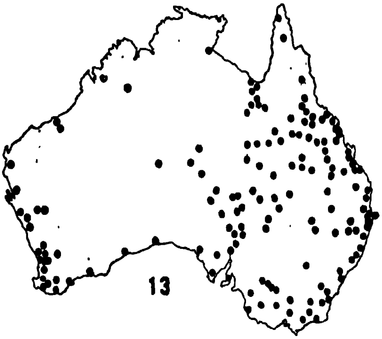
Eye. Map 1, mil (crosses). Map 2, kur (hollow squares), til (triangles).

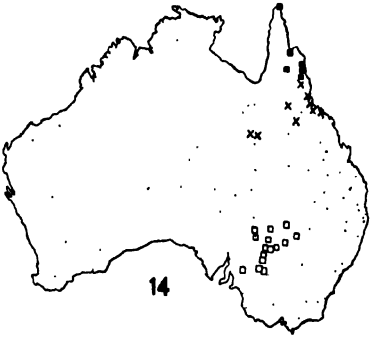
Ear. Map 3, bina (hollow triangles). Map 4, wim (squares). Map 5, manga (triangles), nuri (hollow squares). Map 6, tulpa (circles), kulka (crosses).

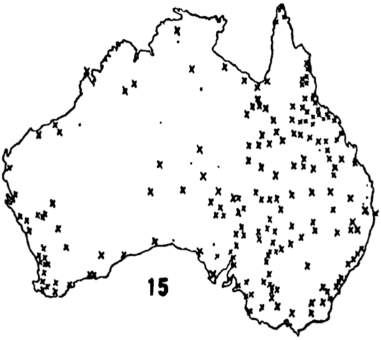


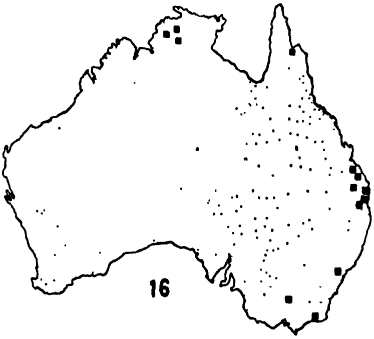
Teeth. Map 7, yira (circles). Map 8, ngalko (triangles). Map 9, milka (squares). Map 10, nandi (hollow squares), karditi (hollow circles), nunathandra (crosses), abu (hollow triangles).

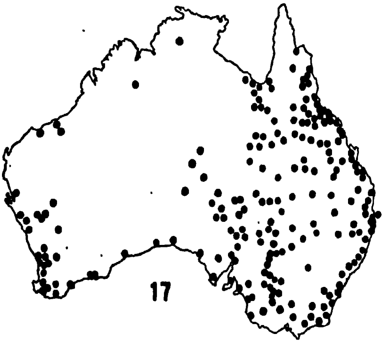
Tongue. Map 11, taling (circles). Map. 12, mat (squares), pulpa (hollow circles), nabi (crosses), kaking (triangles), nandula (V's).

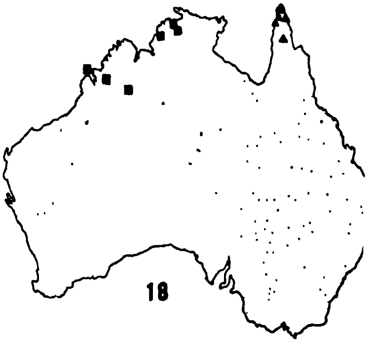








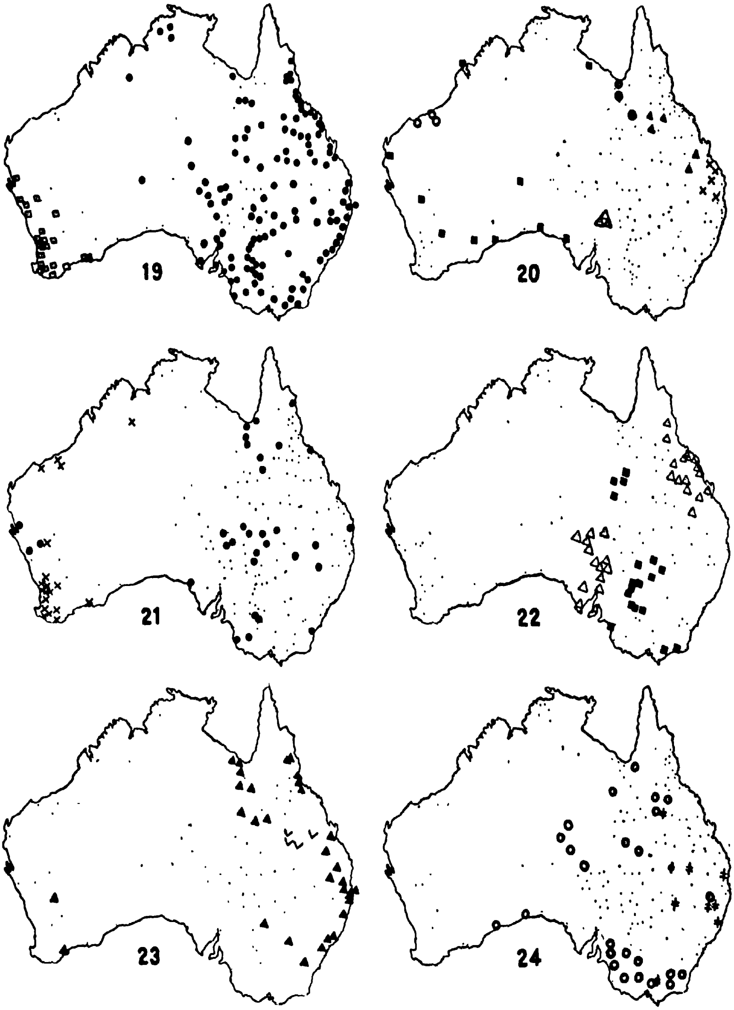




Beard. Map 13, nanka (circles). Map 14, talba (crosses), wakalka (hollow squares), wata (squares).

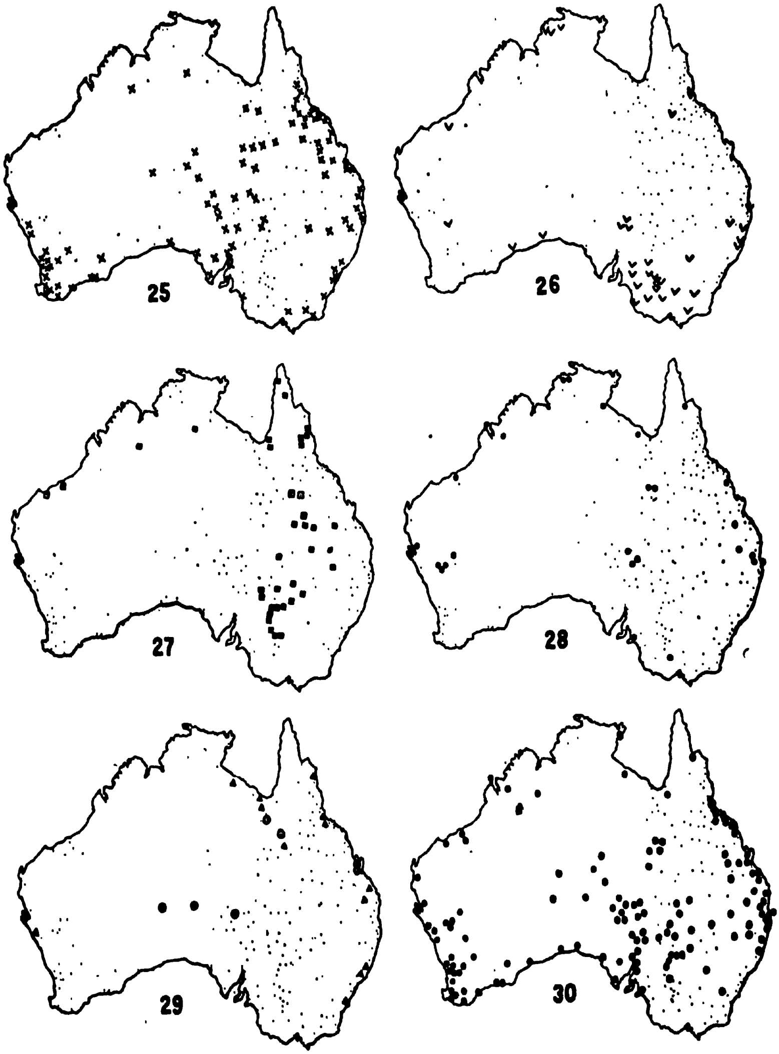
Hand. Map 15, mara (crosses). Map 16, biri (squares).

Foot. Map 17, tina (circles). Map 18, bel (squares), kwa (triangles).



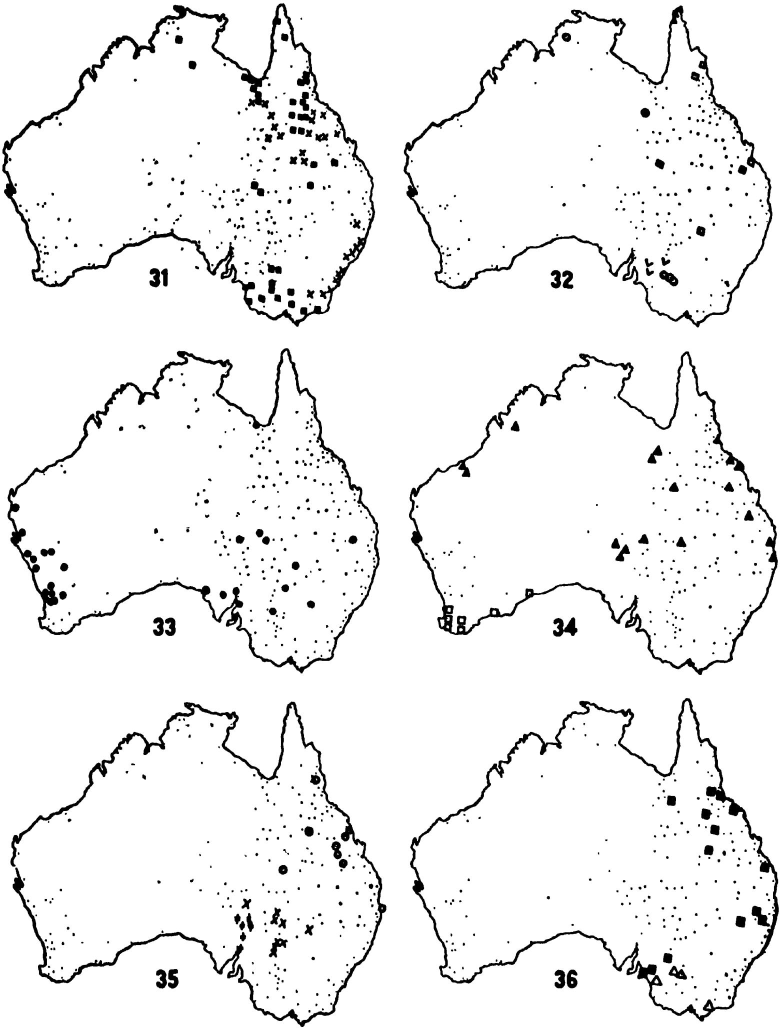
Blood. Map 19, kuna (circles), ngupa (hollow squares). Map 20, yalga (squares), dil (crosses), ma (hollow circles), arti (hollow triangles), yer-kura (triangles).

Bone. Map 21, muku (circles), kwachi (crosses). Map 22, waipu (hollow triangles), pirna (squares). Map 23, direl (triangles), yarun (V's). Map 24, kungun (hollow circles), nim (double crosses).



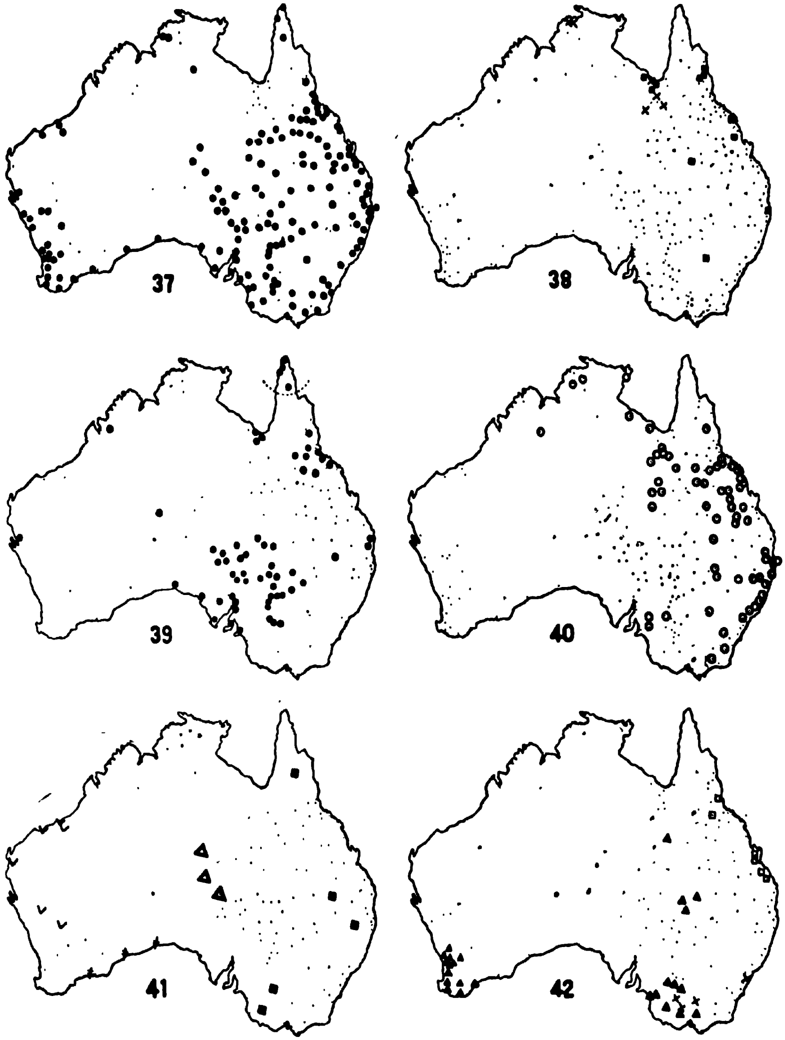
Head. Map 25, ka- (crosses). Map 26, ba- (V's). Map 27, ta- (squares), yulka (hollow squares). Map 28, ma- (circles). Map 29, wal (triangles), ngal (hollow circles).

Nose. Map 30, mula (circles).



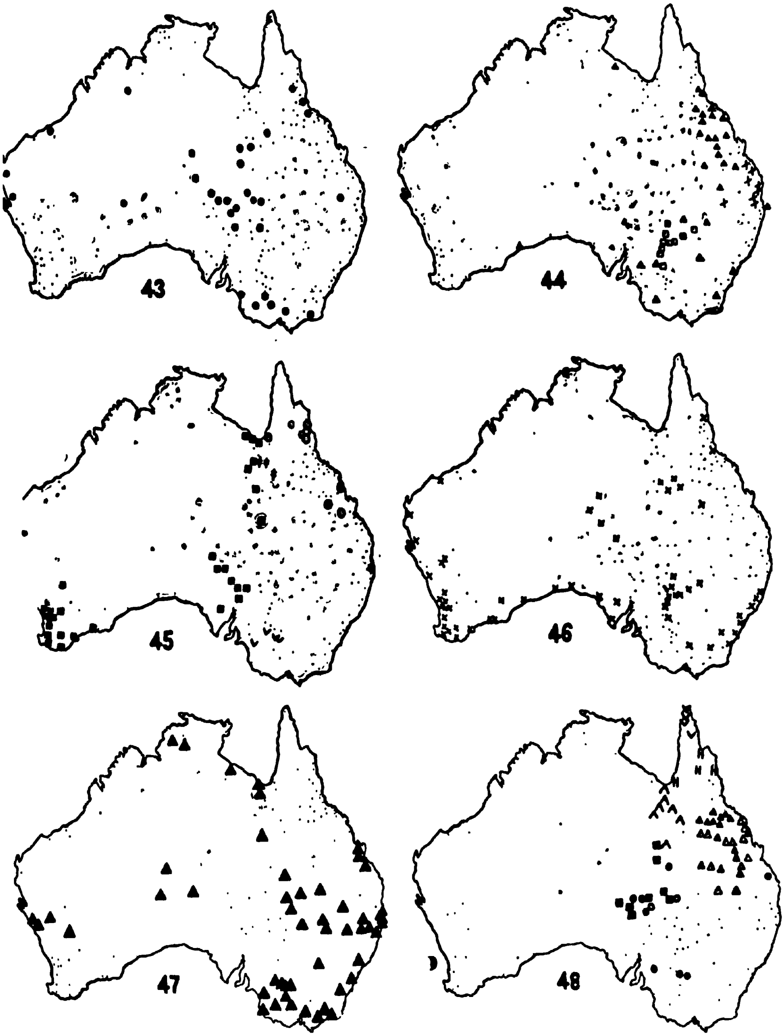
Nose (continued). Map 31, kang (squares), ningar (crosses). Map 32, djandji (hollow circles), runko (V's), pultu (hollow squares), eye (triangles).

Night. Map 33, malti (circles). Map 34, wanga (triangles), kitok (hollow squares). Map 35, tinka (crosses), wilcha (double crosses), kunda (hollow circles). Map 36, ngula (squares), porun (hollow triangles).



Excrement. Map 37, kuna (circles). Map 38, tala (squares), muna (crosses).

Moon. Map 39, pira (circles). Map 40, kibun (hollow circles). Map 41, wilara (V's), taranan (squares), yagin (double crosses), ankacha (double triangles). Map 42, mika (triangles), ngilan (hollow squares), yer (crosses).



Person, blackman. Map 43, karu (circles). Map 44, mari (triangles), wimbadja (hollow squares), dan (crosses). Map 45, yuna (squares), bangil (double crosses), bama (hollow circles), wortongi (V's).

Fire. Map 46, kun- (crosses). Map 47, wi (triangles). Map 48, buri (hollow triangles), maka (squares), turu (hollow circles), ngun (circles), uma (H's), yanu (inverted V's), mo- (V's).

where a substantially true line of linguistic cleavage. Only, there is nothing to show that it ever indicates a primarily important cleavage as he has made it out to be. Still, coupled with his recognition of the distinctiveness of the Darling-Narrinyeri groups, and of a significant change of language at Streaky Bay (where Schmidt's South Central and South-western groups adjoin), Curr's Eastern-Central line shows him to have had a certain degree of linguistic feeling—even though his philological conclusions are mainly compounded from ethnological data, native myths, and pure speculation as to migrations.

Works Supplementary to Curr.

The following are the sources of dialects not compiled by Curr. The numbers refer to Fig. 3. No. 215, W. G. Stretton, Tr. Roy. Soc. S. Austr., XVII, p. 227. Nos. 216 – 220, 222, Elder Expedition, *ibid.* XVI, p. 317. No. 221, W. E. Roth, N. Queensland Ethnogr., Bull. 6, 1903. No. 223, Journ. Elder Exped., Adelaide, 1893. No. 224, R. H. Mathews, J. and Pr. Roy. Soc. N.S.W., XXXV, p. 217. No. 225, H. Kempe, Tr. Roy. Soc, S. Austr., XIV, p. 1. Nos. 226 – 228, T. C. Parkhouse, *ibid.* XIX, p. 1. No. 229, R. H. Mathews, Queensland Geogr. Journ., XVI, p. 69. Nos. 230 – 231, Spencer and Gillen, Northern Tribes of C. Austr., 1904, p. 745. Nos. 232 – 233, 239, J. Mathew, Eaglehawk and Crow, 1899. No. 235 – 238, S. H. Ray, in Cambridge Exped. Torres Straits, III, p. 281.

MOLECULAR SOLUTION VOLUMES IN ETHYL ALCOHOL.

By G. J. Burrows, B.Sc., and F. Eastwood, B.Sc.

[Read before the Royal Society of N. S. Wales, July 4, 1923.]

From a consideration of the solution volumes of a large number of organic and inorganic compounds dissolved in water, Traube[1] calculated the atomic solution volumes of the elements and showed that the molecular solution volume was an additive property. He found that the molecular solution volume (at 15°) in water was equal to the sum of the atomic volumes of the elements together with a constant quantity, 12·4 c.c., and that the molecular volume of a pure (non-associated) liquid was equal to the sum of the atomic volumes together with the constant quantity 25·9 c.c.; that is the co-volume in the case of the homogeneous liquid was 25·9 c.c., and in the case of its solution in water 12·4 c.c. per gram molecule. The difference, 13·5 c.c. represents the contraction that takes place when the substance is changed from a homogeneous liquid to the condition of a solution in water.

The constancy found for the values of the co-volume in the case of aqueous solutions suggests that it is a function of the solvent medium rather than of the dissolved molecule, and one would therefore expect it to vary with the nature of the solvent, and the differences observed by Tyrer[2] for the solution volumes of p-dibromobenzene and diphenyl in a series of solvents can be interpreted in this way. In the case of a non-associated solute in a series of non-associated solvents only slight differences are found in the values of the solution volumes and these vary with the compressibility of the solvent. Larger differences, however, are observed in the case of associated solvents, and there can be little doubt that in these cases the observed volume change results mainly, if not entirely, from a change in the molecular condition of the solvent. A non-associated solute in a non-associated solvent has almost the same volume in solution as it would have in the pure liquid condition, at the same temperature. This is shown by the results previously published by one of us[1] for benzophenone in benzene, and for several of the amides in water-alcohol mixtures, in which the liquids are considered to be dissociated into simple molecules by their mutual effect as the result of mixing.

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[1] Zeit. anor. chem. 1895, *8*, 338; Ber. 1895, *28*, 410, 419, 2722, 2924; Ann. 1896, *290*. 43.

[2] J.C.S., 1910, *97*, 2627.

It was decided to study the solution volumes of various aromatic compounds in ethyl alcohol, in order that information might be obtained as to the magnitude of the co-volume in this solvent; and for this purpose a number of compounds were prepared in a pure condition and the densities of their solutions in alcohol determined at 30°. From these results the molecular solution volumes ϕ of the solutes were calculated from the equation

$$\phi = \frac{m + g}{d_1} - \frac{g}{d_0}$$

where g = the weight of solvent containing the molecular weight m in grams of the solute, and d_0 and d_1 are the densities of the solvent and solution respectively.

It has already been pointed out *(loc. cit.)* that regular variations in the values obtained for the molecular solution volume at different concentrations do not necessarily indicate any variation in the size of the molecule of the solute with change of concentration, but are due rather to the assumption in the use of the equation, that by considering the volume of the solvent to remain constant, any variation in the value of the molecular solution volume of the solute indicates that the volume of the system as a whole varies in the same direction. Such an assumption was shown to be quite wrong by considering the values obtained for formamide-water mixtures from 100% of one to 100% of the other.

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[1] This Journal, Vol. LIII, 74, (1919).

Apart from this, however, the equation is of use in indicating the order of the contraction that takes place when several solutes are dissolved in the same solvent. The number of compounds so far examined does not permit of independent calculation of the values of the atomic solution volumes, so the numbers given by Traube *(loc. cit.)* for aqueous solutions have been used in calculating the values of ΣnA (the calculated molecular solution volume).

In justification of this, it is considered that the molecular volume of a compound consists of (*a*) the volume due to the size of the atoms, (*b*) the space in which the atoms are free to vibrate. There is no reason to suppose that the former factor is not constant for a compound in the liquid state, or in any solvent. Furthermore it is considered that there will be no appreciable difference between the atomic volumes at 30° and at 15°. The atomic constants used in obtaining the figures in the fifth column in the following tables are $H = 3{\cdot}1$, $C = 9{\cdot}9$, O (in OH) $= 2{\cdot}3$, $Cl = Br = 13{\cdot}2$, N (NH_2) 1·5, ring formation $= -8{\cdot}1$. As regards the value for NO_2, this was obtained as follows: in the first place since benzene and toluene are both non-associated liquids, and since the solution volume of toluene was found to be almost identical with that of the pure liquid, it was considered that the same would be the case with benzene. The density of benzene at 30° is 0·8612 whence its molecular volume (in the liquid state) is 90·6. The molecular solution volume should be almost identical with this. Again, if from the molecular solution volume of toluene (106) one subtracts the value of CH_2 as given by Traube, the result is 90; the same result is obtained by calculation from chlorobenzene. The value found for nitrobenzene was 98, so that the replacement of H by NO_2 = 8, or NO_2 = 11·1. This value has been used in the calculations for ortho- meta- and para-compounds.

The substances examined include compounds which are known to be associated and others which are not. It will be seen from the tables that in the case of toluene the value found for the molecular solution volume is almost identical with that of the pure liquid. But in the case of an associated liquid such as aniline there is a marked difference between the molecular volume of a liquid and its volume in solution. Generally, as the degree of association increases so does the difference between the molecular solution volume and the molecular volume of the pure liquid.

In the case of toluene, bromobenzene and chlorobenzene the differences between the observed and calculated molecular solution volumes are 20, 22 and 20 respectively. Taking these three liquids as examples of non-associated solutes it follows that in such cases the co-volume has a value of 20 c.c., whereas in aqueous solutions (at 15°) it is only 12·4 c.c., a result in harmony with the view put forward by Tyrer *(loc. cit.)* and independently by one of us *(loc. cit.)* that the contraction which accompanies the process of solution is a function of the compressibility of the solvent. Furthermore, taking 22 and 12 c.c. as the approximate co-volumes of a solute in ethyl alcohol and water respectively, it follows that of the observed contraction that takes place when alcohol and water are mixed, nearly two-thirds is attributable to the compressibility of the alcohol, and one third to that of the water.

From cryoscopic results aniline and its derivatives are known to be associated in benzene solution, and therefore probably also in the pure liquid state. From the following tables it will be seen that the co-volumes, *i.e.*, the differences between the observed molecular solution volumes and those calculated from the atomic constants are less than ·20 c.c. for aniline, p-chloroaniline, p-bromoaniline, p-toluidine, m- and p-nitroaniline and p-chlor-acetanilide. It would appear therefore, that the solution of a non-associated solute in alcohol causes a contraction in volume represented by about 20 c.c. per gram molecule of solute, in dilute solution, and that a smaller contraction indicates that the solute is associated in the liquid state. It is not considered that these results indicate that the solute is associated in solution, but rather that the effect of such a solute on the associated molecules of the alcohol causes a change in the complexity of the latter, and therefore in its volume.

From the values obtained for the molecular volumes there is no evidence of association in chlorobenze, bromobenzene, nitrobenzene, o-nitrophenol, o-nitrotoluene, or picric acid; p-nitrophenol and p-nitrotoluene, however, appear to be associated.

In the following tables A is the number of grams of the solute dissolved in 100 grams of alcohol, v_s is the specific solution volume of the solute and is $= \left(\frac{100+A}{d_1} - \frac{100}{d_0}\right) \div A$, ϕ is the molecular solution volume calculated from the equation previously given, ΣnA is the molecular solution volume calculated from the atomic constants, and $\triangle$ is the co-volume and is equal to $\phi - \Sigma nA$. The alcohol used in the experiments was previously dehydrated with calcium turnings; it will be noticed that the density of the alcohol used in the first five experiments differs slightly from that in the others, but this does not effect the validity of the numbers given for the solution volumes. The densities were determined with a pyknometer of about 22 c.c. capacity, and the temperature of all the experiments was 30·0°. The figures given for the densities of the solutes in the liquid condition were either taken directly from the literature, or have been extrapolated from values given at other temperatures.

Bromobenzene in alcohol—(d_0 = 0·78081). The density of bromobenzene at 30° is 1·482, from which the molecular volume of the pure liquid is 106.

A	d_t	v_s	ϕ	ΣnA	Δ
3·3141	0·79327	0·654	102·7	80	22
4·3057	0·79694	0·653	102·6		
6·0082	0·80301	0·656	103·0		
7·0619	0·80666	0·659	103·4		

Chlorobenzene in alcohol—(d_0 = 0·78081). The molecular volume of chlorobenzene calculated from its density at 30° (1·102) is 102.

2·9425	0·78773	0·888	100·0	80	22
5·2469	0·79287	0·890	100·0		
6·7932	0·79623	0·891	100·2		

Toluene in alcohol—(d_0 = 0·78081). The molecular volume of toluene at 30° calculated from its density (0·8566) is 107.

3·2085	0·78322	1·154	106·2	86	20
4·1517	0·78386	1·156	106·4		
5·6473	0·78188	1·157	106·8		
8·9703	0·78689	1·160	106·8		

Aniline in alcohol—(d_0 = 0·78081). The density of aniline at 30° is 1·013 whence the molecular volume of the liquid is 91·7.

2·2859	0·78592	0·908	84·6	74·5	10
4·1188	0·78976	0·910	85·1		
7·7846	0·79693	0·922	85·9		

Nitrobenzene in alcohol—(d_0 = 0·78081). The density of nitrobenzene at 30° is 1·201, whence its molecular volume is 102.

A	d_1	V_s	ϕ	ΣnA	Δ
5·1994	0·79558	0·800	98·5		
6·9064	0·80045	0·794	97·8	78	20
8·9039	0·80542	0·802	98·8		

Ortho nitrophenol in alcohol—(d_0 = 0·78100). The density of o-nitrophenol at 30° is 1·329, whence the molecular volume is 105.

3·6882	0·79339	0·718	99·9	80	20
5·5525	0·79945	0·718	99·9		

Para nitrophenol in alcohol—(d_0 = 0·78100). The density of the solute at 30° is 1·346, whence the molecular volume is 103.

0·9624	0·78452	0·678	94·3	80	15
1·8684	0·78775	0·682	94·9		

Picric acid in alcohol—(d_0 = 0·78100).

1·0981	0·78614	0·510	116·9	96	21
2·2701	0·79153	0·513	117·5		

Para nitroaniline in alcohol—(d_0 = 0·78100).

0·6583	0·78346	0·664	91·8		
0·8356	0·78412	0·666	92·0	82·5	10
0·9735	0·78456	0·678	93·6		

Meta nitroaniline in alcohol—(d_0 = 0·78100). The density of the solute in the liquid condition at 30° is 1·296, whence the molecular volume is 106.

2·4974	0·78979	0·696	96·1	82·5	14
2·7685	0·79069	0·698	96·4		

Para chloroaniline in alcohol—(d_0 = 0·78100). The density of the solute at 30° is 1·207, whence the molecular volume is 106.

1·2343	0·78506	0·737	94·1	85	10
1·3805	0·78545	0·747	95·3		

***Para bromoaniline in alcohol*—(d_0 = 0·78100).**

A	d_1	V_s	ϕ	ΣnA	Δ
3·4614	0·79562	0·577	99·3	85	15
4·9435	0·80156	0·583	100·3		

***Para toluidine in alcohol*—(d_0 = 0·78100). The density of the solute in the liquid condition at 30° is 0·9788, whence the molecular volume is 109.**

2·7618	0·78675	0·932	99·8	90·6	10
4·1152	0·78931	0·939	100·6		

***Ortho nitro-toluene in alcohol*—(d_0 = 0·78100). The density of the solute at 30° is 1·154, whence the molecular volume is 118·8.**

3·2342	0·78972	0·829	113·7	94	20
16·5683	0·82051	0·847	116·1		
44·9215	0·87101	0·853	117·0		
108·1933	0·94148	0·860	118·0		

***Para nitro-toluene in alcohol*—(d_0 = 0·78100). The density of the solute in the liquid condition at 30° is 1·145 whence the molecular volume is 119.**

1·0409	0·78412	0·786	107·8	94	14
1·1255	0·78436	0·788	108·1		

***Para chlor-acetanilide in alcohol*—(d_0 = 0·78100).**

1·2999	0·78515	0·754	127·8	116	12
2·2048	0·78794	0·758	128·4		

TWO ADDITIONAL SPECIES OF LEPTOSPERMUMS.

By EDWIN CHEEL.

[*Read before the Royal Society of N. S. Wales, July 4, 1923.*]

IN continuation of my studies of this genus[1] I find the two species dealt with are of particular interest, as the seed characters of the new species are such as to enable me to define a distinct group in a key to the species which I am preparing for publication, and the *L. coriaceum* is interesting from a geographical point of view as well as some structural differences.

LEPTOSPERMUM MICROCARPUM *sp. nov.*

Frutex 18 – 24 dm. altus, ramis gracilibus flexilibus, cortice glabris delapso, ramulis foliisque juvenilibus primum hirsutis demum glabresentibus; foliis coriaceis, plus minusve fascicularibus, ovato-lanceolatis, concavis præsertim ad apicem, pungentibus, trinervis; calycis tubo hirsuto, pedicellis brevibus 2 – 4 mm. longis; petalis albis, ovatis, ad basim leviter attenuatis, 5 mm. longis; sepalis brevissimis, 1 mm. longis, pubescentibus vel sericeohirsutis; staminibus 20 – 25; ovario 3 – 4—loculari (rare 5); valvis vix exsertis fructo pedicellato, parce hirsuto.

Shrub with slender whip-stick like branches up to 6 or 8 feet high, the bark peeling off in thin flakes and then becoming perfectly smooth, branchlets hairy when quite young, as well as the juvenile leaves but becoming glabrous with age. Leaves coriaceous, more or less clustered, ovate to ovate-lanceolate, more or less incurved especially at the tips, which finally become almost pungent-pointed through the convoluted points, three-nerved, 7 – 12 mm. long. 3 – 4 mm. broad, thickly studded with oil-glands. Flowers solitary in the axils of the leaves or rarely in pairs; calyx-tube hairy, on short pedicels varying from 2 to 4 mm. long. Sepals very short scarcely exceeding 1 mm. long, pubescent or silky-hairy. Petals white, ovate, narrowed at the base, about 5 mm. long. Stamens about 20 to 25. Ovarium usually 4-celled or occasionally 3 or 5-celled, the valves very slightly raised above the rim of the calyx-tube. Fruits pedicellate, slightly hairy. Seeds few in the cells, the perfect ones quite distinct from the sterile ones, and in this respect they may be the means of forming a distinct group or section, between sections Fabricia and Euleptospermum, as I have noticed several species with similar seed characteristics.

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[1] This Journal, 1918, p. 175; 1919, p. 120; 1920, p. 233 and 1922, p. 166.

Herbarium specimensof this speciesat first sight resemble *L. arachnoideum*, but the habit, fruits and seeds are quite distinct. The leaves and pedicellate flowers somewhat resemble some forms of *L. stellatum*, hence it has been mistaken for that species, but the different shaped fruits with fewer cells and pungent-pointed leaves which are less silky in the adult stage, at once separate it from the latter, which have flat membranous leaves and are not at all pungent-pointed. It has also been confused with *L. scoparium*, but is easily distinguished from that species by the pedicellate hairy fruits.

Habitat—New South Wales—Acacia Creek, Macpherson Range,[1] W. Dunn, September; Murwillumbah, R. A. Campbell (No. 14) January; Copmanhurst, H. M. R. Rupp, September; E. Cheel, November; Mount Mullengen near Ramornie, W. F. Blakely and D. W. C. Shiress, July.

Queensland—Stanthorpe, J. L. Boorman, July; Top of Mount Cooroy, F. M. Baily and Simmonds, November, communicated by Mr. C. T. White under No. 13; Mount

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[1] Acacia Creek is in New South Wales, but it is easiest to go to Killarney (Q) Railway Station to get there.

Ooroora, Wide Bay District, C. T. White, March, (No. 1892); Glasshouse Mountain, J. Shirley, September.

LEPTOSPERMUM CORIACEUM *nov. comb.*

I propose to adopt the above specific name for a series of specimens which appear to be intermediate between *L. lævigatum* and *L. Fabricia*, but to me more closely related to the latter. It was originally described by Mueller under the name *Fabricia coriacea.*[1] Bentham (B. Fl. iii, 103) included it under *L. lævigatum* as a doubtful variety—var. *minus* F. Muell., with the remark that it was "perhaps a distinct species."

The localities given by Bentham are as follows:—

New South Wales—Darling River, Victorian Expedition.

Victoria—N. W. Desert, Lockhardt, Morton, Dallachy; scrub near the mouth of the Murray, F. Mueller.

South Australia—St. Vincent's and Spencer's Gulfs to the Murray, F. Mueller and others. Specimens from Murray Bridge collected in January, 1907, by Mr. J. H. Maiden were recorded under the name of *L. lævigatum.*[2] In the same work,[3] Mr. J. M. Black refers to the species with the following interesting remarks:—

"Sandhills near Ooldea.—These specimens are remarkable for having the whole calyx covered with appressed silky hairs (much as in *L. lanigerum*), but in the ripening of the fruits the lobes fall off and the calyx-tube becomes glabrous, which is the normal condition in more southern forms; cells 6—8, summit of capsule much exserted and convex; leaves lanceolate-cuneate, 15 – 25 mm. long. Similar specimens are in the Tate Herbarium from 60 miles north of Point Bell, a position which would be about 100 miles south-east of Ooldea. (Quite plentiful all through the sandhills, growing into large bushes 15 feet tall.)"

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[1] Miq. in Ned: Kruidk. Arch. IV, 147, 1856.

[2] Trans. and Proc. Roy. Soc. S.A., XXXII, 260, 1908. [3] Vol. XL, 70, 1916; Vol. XLI, 385, 1917.

Specimens of *L. lævigatum* of J. A. Kershaw, Ooldea Flats,[1] have been compared by Mr. W. Laidlaw, Government Botanist, National Herbarium, Victoria, who states that they prove to be *L. coriaceum.*

In the National Herbarium, Sydney, there are some fine specimens collected at Ooldea in June, 1909, by Mr. Henry Deane when surveying the Transcontinental Railway. Sketches were made of the flowers, and both Mr. Maiden and the late Mr. Betche were of the opinion that the species was more closely allied to *L. Fabricia* than to *L. lævigatum*, but in the absence of better material of *L. Fabricia* for a comparison, it was left in abeyance.

I propose now to amplify the descriptions that have been given by submitting the following:—Plants of a shrubby growth, reaching a height of about 15 feet. Branches and branchlets glabrous; leaves lanceolate or more or less cuneiform, obtuse, but the central nerve or midrib protruding somewhat and ending in a mucro, hence the leaves are occasionally somewhat pungent-pointed; glabrous, thick, obscurely 3 or rarely 5-nerved, oil glands present, but scarcely visible owing to the thickness of the texture. Flowers very shortly pedicellate, axillary enclosed in comparatively stiff brownish coloured bracts. Bracteole rather large, more or less convolute with age and silky-hairy inside, especially near the apex. Calyx-tube covered with a dense silky tomentum, lobes ovate, also densely hairy on both the inner and outer surfaces. Petals white, oblong, the claw not very narrow at the base, and with a few hairs at the attachment. Stamens about 25 – 30. Ovarium 5 – 8 celled, the valves or summit of the capsule convex and exserted above the rim of the calyx-tube.

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[1] Vic. Nat., XXXVIII, 130, 1922.

Although this species has affinities with *L. Fabricia*, it may be distinguished by the smaller and narrower leaves which in some specimens are more or less pungent-pointed, and the fewer cells of the fruits.

Additional localities to those mentioned above are:—Victoria—Carrum, W. R. Guilfoyle, June; Nhill, J. Staer, April; Mallee District, C. Walter, October; Sandringham, A. J. Tadgell, August and September.

I desire to express my best thanks to Mr. J. H. Maiden, I.S.O., F.R.S., Government Botanist, Sydney, and Mr. W. Laidlaw, Government Botanist, Victoria, for their kindness in permitting me to use the records in their respective Herbariums.

THE ESSENTIAL OILS OF CALLISTEMON LANCEOLATUS AND C. VIMINALIS.

By A. R. PENFOLD, F.C.S.,

Economic Chemist, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, July 4, 1923.*]

THE essential oils described herein were obtained from the leaves and terminal branchlets of two well known Myrtaceous shrubs, or trees, commonly called 'Bottle Brushes,' which grow fairly plentifully in New South Wales and the coastal districts of Queensland. The examination of the essential oils has not revealed any striking difference between the two species, in fact it would be almost impossible to distinguish the individual oils. There does, however, appear to be two forms of the species, *viminalis*, which confirms the previously expressed opinion of Mr. E. Cheel,[1] as the oils from Copmanhurst and Dalmorton of New South Wales differ from those obtained from the two Queensland localities, provided, of course, the time of year has not greatly influenced the composition of the oil. So far as the investigation has been carried there is a greater difference existing between the two forms of *C. viminalis* than between the two species under examination.

The oils are very similar to those obtained from the cineol group of the Eucalypts and being free from the objectionable volatile aldehydes and phellandrene, would be of considerable value as a medicinal oil but for the extremely poor yield, 0·2% as compared with 2 to 3% obtained from some of the Eucalypts.

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[1] Proc. Linn. Soc. N.S.W., 1920, p. 221.

This is unfortunate as Dr. T. L. Bancroft of Eidsvold, Q., who is greatly interested in the examination of Australian essential oil yielding plants and their development, furnishing a supply of the leaves of *C. viminalis* for examination of its essential oil, wrote:—"if there should be an essential oil of commercial value in the leaves of the Red Tea-Tree it could easily be obtained as the tree is extremely abundant along the banks of rivers here. It is 12″ to 18″ in diameter at the butt and about 30 feet in height and only grows at the water's edge along the whole length of the Burnett River. It is very willow-like in habit."

C. LANCEOLATUS (De Candolle).

The botany of this shrub or small tree is described in Bentham's "Flora Australiensis," Vol. III, p. 120. It is well known by its beautiful long crimson coloured stamens which are responsible for its popular name "Bottle Brush." It is usually found growing in swampy situations extending up to about Gloucester on the North Coast of New South Wales. Leaves and terminal branchlets were procured from Manly, a few miles north of Sydney, and Gosford, 50 miles north of Sydney, a total of 459 ℔s. being obtained. The percentage yield of oil varied from 0·06% to 0·22%, the lower yield being due to the more stunted growth of the shrubs growing in an exposed position at Manly close to the ocean.

The Essential Oil.

The essential oils were of a pale lemon colour of pronounced cineol odour, and closely resembled in general characters a cineol Eucalyptus oil. The principal constituents, so far identified, were found to be cineol, dipentene, limonene, terpineol, sesquiterpene and small amount of phenols.

Experimental.

459 ℔s. weight of leaves and terminal branchlets from the places mentioned, yielded on distillation with steam,

crude oils, possessing the chemical and physical characters shown in table :—

Date.	Locality.	Weight of Leaves.	Percentage Yield of Oil.	Specific Gravity $\frac{15}{15}$° C.	Optical Rotation.
4/10/1922	Long Reef near Manly Sydney.	134¼ lbs.	0·06%	0·8892	–0·52°
22/11/1922	Gosford, N. S. Wales	325 lbs.	0·22%	0·9075	–0·5°

Refractive Index 20° C.	Solubility in alcohol. (by weight).	Ester No. hot sap. 1½ hours.	Ester No. hot sap. 1½ houre after acetylation.	Cineol in crude oil P=Phosphoric acid R=Resorcin method.
1·4716	soluble 10 vols. 80%	9·18	...	35% R.
1·4668	soluble 7 vols. 70%	5·55	30·32	53% P.

On distillation, the crude oils behaved, as follows:—

4/10/1922 (Long Reef). Only 30 c.c. available.

24 c.c. came over at 60 – 65° C. at 10 mm. which on redistillation boiled at 174 – 176° C. at 762 mm. The distillate possessed the following constants:—Specific gravity $\frac{15}{15}$° C. 0·8410, optical rotation – 3·2°, refractive index 24° C. 1·4718.

22/11/1922 (Gosford). 100 c.c. at 10 mm:—

56% at 60 – 65° C.—Specific gravity $\frac{15}{15}$° C. 0·9017; optical rotation – 0·65°; refractive index 1·4609 (22½° C.)

30% at 65 – 88° C.—Specific gravity $\frac{15}{15}$° C. 0·9075; optical rotation – 1·00°; refractive index 1·4619 (22½° C.)

4% at 99 – 105° C.—Specific gravity $\frac{15}{15}$° C. 0·9224; optical rotation – 0·30°; refractive index 1·4821 (22½° C.)

Determination of Terpenes.—On removal of cineol from the fraction distilling at 60 – 65° C. at 10 mm. by means of 50% resorcin solution the residual oil possessed a specific gravity $\frac{15}{15}$° C. 0·8400, optical rotation −3·35°, and refractive index 24½° C. 1·4719. On addition of bromine to a glacial acetic acid solution a copious precipitate of tetrabromide was obtained, which on recrystallisation from ethyl acetate melted at 124 − 125° C., thus indicating the presence of dipentene with a small amount of limonene.

Determination of Cineol.—The percentage of cineol present was determined in both lots of oil by the phosphoric acid method, for the confirmation of which see under *C. viminalis.*

Determination of Terpineol.—The small fraction of the Gosford sample distilling at 99 − 105° C. at 10 mm., 4½ c.c., which possessed a pronounced odour of this alcohol, readily yielded a phenylurethane of melting point 111° C.

Determination of Sesquiterpene.—The portion of oil from Gosford sample boiling above 105° C. at 10 mm. was redistilled several times over sodium when a small quantity was obtained boiling at 130 − 138° C. at 10 mm., of specific gravity $\frac{15}{15}$° C. 0·9291, inactive, and refractive index 21° C. 1·4960. It gave the usual colour reactions with bromine vapour and acetic anhydride characteristic of sesquiterpenes from the Myrtaceæ.

Phenol.—Small quantities of phenolic bodies were present to the extent of about 0·5%, which differed from similar constituents in the oil of *C. viminalis* in giving an indifferent brown colouration with ferric chloride in alcoholic solution.

CALLISTEMON VIMINALIS (Sol.) Cheel.

The botany of this tree which is closely related to *C. lanceolatus* and likewise called a "Bottle Brush," has been fully worked out by Mr. E. Cheel of the National Herbarium, Sydney, for a description of which Mr. J. H. Maiden's "Forest Flora of N.S.W., Vol. VII, page 15, should be consulted.

It is a tall tree, growing from 15 feet to 60 feet in height, sometimes up to 75 feet, and 8 to 12 inches in diameter, and although it closely resembles *C. lanceolatus* it is readily distinguished from such crimson flowering species by its tree-like habit, and drooping willowy appearance, especially if examined in the field. It is not unusual for specimens of this tree to be confused with *C. lanceolatus*, particularly if compared with herbarium material, and on this account I have to express my thanks to the author of the species, who when recommending the writer to undertake the examination of its essential oil in 1918, kindly provided the authentic specimens for the purpose, and for his kindness in confirming the authenticity of the material examined.

This tree is a denizen of the banks of rivers and creeks, and occurs widely distributed, extending from Gloucester in Northern New South Wales up through the coastal districts of Queensland.

The leaves of the four consignments distilled were much narrower than the two lots of *C. lanceolatus*, which were somewhat broad. Leaves and terminal branchlets were obtained from Copmanhurst and Dalmorton of N. S. Wales in May and June 1920, and Dr. T. L. Bancroft of Eidsvold, Queensland, kindly furnished an excellent supply of material in September 1922. Mr. J. J. Jordan of Gladstone, Queensland, in September 1921, kindly distilled 160 ℔s. leaves on the writer's behalf. In all 895 ℔s. weight of leaves were distilled with an average percentage yield of 0·2%.

The essential oil from the New South Wales material differs somewhat from the Queensland in containing *d*-α-pinene in fair quantity, higher phenol content and much lower percentage of cineol, as well as an apparent absence of dipentene. This points to the tree in the former State being a form of the species, especially as the bark is different, being of a papery nature.

The Essential Oils.

The essential oils obtained from the New South Wales consignments were of an intense red colour with a pronounced amylic odour, followed by a secondary one of cineol. The sample of oil from Gladstone, Queensland, was also of a reddish colour but much lighter, and strongly resembled a high cineol oil. These oils were coloured red on account of the phenol present acting on the steel coil used in the condenser, which was subsequently replaced by one of pure tin. The oil from material supplied by Dr. Bancroft was, therefore, of a pale yellow colour.

The principal constituents of the oil from the New South Wales form, so far determined, were *d*-*a*-pinene, cineol (about 30%), phenol (2%), together with sesquiterpene, and probably terpineol. (β-pinene and dipentene were not detected). A small quantity of amyl alcohol appeared to be present.

The constituents identified in the Queensland oils (*C. viminalis*) were cineol (60—80%), dipentene, limonene, terpineol, sesquiterpene, and phenol (about 0·5%).

Experimental.

895 lbs. weight of leaves and terminal branchlets of the two forms procured from the districts mentioned, yielded on distillation with steam, the following crude oils, possessing the chemical and physical constants shown in table:—(See page 137.)

On distillation the crude oils behaved, as follows :—

N.S. Wales form (2 lots), both yielded 85% distilling below 185° C. (u.c.) at 768 mm.

Eidsvold, Q., (100 c.c. distilled at 761·5 mm. gave :—

80% at 170 - 176° C. sp. gr. $\frac{15}{15}$° C. 0·9090, opt. rot. $-0·4°$ and ref. index 20° C. 1·4609.

10% at 176 - 190° C. sp. gr. $\frac{15}{15}$° C. 0·9159, opt. rot. $-2·3°$ and ref. index 20° C. 1·4630.

Date	Locality	Weight of leaves	Percentage yield of oil	Specific gravity $\frac{15^\circ}{15}$ C.	Optical rotation	Refractive index at 20° C.	Solubility in alcohol	Ester No. hot 1½ hours	Ester No. hot 1½ hours after acetylation	Cineol in crude oil. P=phosphoric acid method R=resorcin method
				C. viminalis New South Wales form.						
26/5/1920	Copmanhurst, N.S. Wales.	288 lbs.	0·22%	0·8980	+12·8°	1·4678	soluble 3·8 vols. 80%	17·64	38 87	28% P 38% R
22/6/1920	Dalmorton, N.S. Wales.	221 lbs.	0·13%	0 8890	+14·1	1·4677	soluble 5 vols. 80%	13·91	34·11	27% P 36% R
				C. viminalis from Queensland.						
26/9/1921	Gladstone, Queensland.	160 lbs.	0·22%	0 9205	inactive	1·4609	soluble 1·1 vols. 70%	5·5	21·56	77% P
25/9/1922	Eidsvold, Queensland. (Dr. Bancroft)	226 lbs.	0·21%	0·9133	– 1°	1·4634	soluble 1·4 vols. 70%	7·34	29·62	63% P

Determination of the principal Terpenes.—N.S. Wales form. After removal of cineol in usual manner, the residual oil distilled at 156 - 160°C. at 764 mm., the distillate having: sp. gr. $\frac{15}{15}^{\circ}$ C. 0·8639, optical rotation + 31·2°, and refractive index 20° C. 1·4663. On mixing with an equivalent volume of *l*-*α*-pinene $[\alpha]_D$ - 50·18°, a copious yield of nitrosochloride was obtained, which melted and decomposed at 109° C., thus proving it to be *d*-*α*-pinene.

Eidsvold, 25/9/22. Removed the cineol from both fractions of oil distilling below 190° C., and redistilled the residual oil, collecting the portions which came over below and above 170° C. separately. The lower boiling distillate possessing an optical rotation of + 0·9° readily yielded a nitrosochloride which melted and decomposed at 109° C. That distilling above 170° C. with an optical rotation of about - 20° when dissolved in glacial acetic acid and bromine added, gave a tetrabromide of melting point 124° C. after recrystallisation from ethyl acetate, thus showing the presence of dipentene with a small quantity of limonene.

Determination of Cineol.—The cineol regenerated from the resorcin solution used in its separation from the terpenes, possessed the following characters:—B. point 175 - 176° C. at 764 mm., sp. gr. $\frac{15}{15}^{\circ}$ C. 0·9308, inactive, refractive index 20° C. 1·4575. Confirmation was obtained by the preparation of the iodol compound which melted at 112° C.

Determination of Sesquiterpene.—Too small a quantity of oil was available for the examination of this constituent, its presence being merely determined in the portion of oil distilling above 200° C. by the usual colour reactions characteristic of these bodies in Australian essential oils.

Determination of Phenols.—Phenolic bodies were found to occur to the extent of 2% in the oil of the N.S. Wales form which gave a blood red colour with ferric chloride in alcoholic solution, thereby closely resembling, if not identical with, tasmanol or phenols of that type. This group is at present under investigation by this laboratory as very little is known about them.

In conclusion I have to express my thanks to Mr. J. J. Jordan of Gladstone for kindly distilling a quantity of the leaves of *C. viminalis* and forwarding the oil, to Dr. T. L. Bancroft of Eidsvold, Q., for the excellent supply of leaves kindly furnished at his own expense, and Mr. F. R. Morrison, A.T.C., Assistant Chemist, for his usual assistance in these investigations.

CANCER OF THE EAR OF SHEEP:

A CONTRIBUTION TO THE KNOWLEDGE OF CHRONIC IRRITATION AS A SECONDARY FACTOR IN THE CAUSATION OF CANCER IN THE LOWER ANIMALS.

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[*Read before the Royal Society of N. S. Wales, August 1, 1923.*]

AMONGST the indirect causes of cancer formation in human beings, chronic irritation is accepted as being an established factor. As examples, there are the so-called occupational cancers, *e.g.*, Chimney sweep's cancer of the scrotum, multiple epithelioma of the skin in paraffin and aniline dye workers, X Ray cancer, etc. In other instances, cancer has been observed arising from the chronic irritation and inflammation brought about by such agencies as a jagged tooth, indolent ulcers, and in smoker's cancer of the lips, pharynx and larynx, cancer of the skin in chronic eczema, etc. In veterinary pathology, however, chronic irritation is by no means universally accepted as giving rise to cancer in the lower animals. The arguments are various but the principal one appears to be that there has been no direct evidence brought forward to prove such contention, and, furthermore, that in parts which are notoriously the subject of chronic irritation, *e.g.*, saddle and collar galls in horses, and in dogs, in countries where they are used for haulage purposes, the parts constantly rubbed by the harness, one does not find cancer resulting. Moreover, the human breast is a common site for cancer, and it is held by some human pathologists that the step between chronic mastitis and cancer is short. It is even stated that the proportion of cases of chronic mastisis in women developing into cancer is from 10 – 15%.[1] Contrasted with this state of affairs in the human being, we have the well known fact that the mammary gland of the cow is frequently the seat of injuries and that chronic mastitis from various causes is common. Yet cancer of the cow's udder is rare. It is from facts such as these that veterinary pathologists speaking generally, have preferred to consider as "not proven," the question of the natural production of cancer in the lower animals as a result of chronic irritation.

So far as chronic irritation as a major factor in cancer formation is concerned, veterinary pathologists have been justified in refusing to indiscriminately apply the accepted findings relating to human pathology, (although the latter may be correct as regards man), to the lower animals without further definite evidence concerning the latter, that similar mechanical causes will produce similar effects in the same anatomical situations in different species, for, as has been pointed out by a number of authorities, it is necessary to guard against false analogies when pathological processes are compared between man and the lower animals. In the case of cancer, the same cause may be in operation but it appears evident that the reactions of similar tissues in different species may not be in the same degree. Consequently what may eventually result in a malignant growth in one, will probably remain a chronic inflammatory lesion in another. It is perhaps desirable to point out that one is not referring here to the cutaneous cancers artificially produced in some of the smaller animals by the application of tar, soot, paraffin etc. Furthermore, it is hardly necessary to state that it is realised no one maintains that chronic inflammation arising from any cause must inevitably be followed by cancer, since it is very obvious that the vast majority of cases of chronic inflammation either eventually recover if the irritant be removed, or never progress beyond that stage.

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[1] Ewing, Neoplastic diseases, 1919. This statement is disputed.

As an illustration of the different reaction of the tissues of different animals, reference is made to the experimental production of "Paraffin cancer." It has been recently shown that epitheliomata could be experimentally produced in mice by the application of coal tar to the skin, but it was unsuccessful in guinea pigs, rats and rabbits.

It is not intended here to enter into a discussion as to why any particular site should be more susceptible to neoplastic formation in one species than another, but veterinary authorities have drawn attention to the peculiar differences in the relative frequency of malignant growths, especially the carcinomata, in certain situations in man and the domesticated animals. Reference has already been made to the mammary gland and the skin. Other examples may be given, *e.g.*, the alimentary tract is one of the common sites of cancer in man. It is uncommon in the herbivora, and much less frequent in dogs and cats than man. Again, in horses and cattle, carcinoma of the nictitating membrane and the caruncle is relatively common, much more than other species including man.

It is difficult to draw any useful comparison between man and the domesticated animals as to the actual frequency of the epithelial cancers, since they mainly occur in adult and old age, and most of the animals used for human food are killed young, or in the prime of life. Only domestic pets are as a rule kept until they reach old age.

In view of the desirability of collecting as much direct evidence as possible as to chronic inflammation in the lower animals being followed by malignant growth, this contribution is made.

The condition affecting the ears of sheep in Australia and termed by sheep men "cancer," is fairly common. Although taking into consideration the millions of sheep in this country, the actual percentage is not a high one, (actual statistics do not exist), yet every year, especially during the shearing season when the sheep are observed at close quarters, it is generally possible to obtain several cases from various localities. As a rule, in the ordinary course of events when such cases are detected by the owner, the animal, if the condition is advanced, is destroyed. The carcase is not used for food. The slight cases are either not detected, or are allowed to pass without any action being taken. It is seldom that pronouncedly affected animals are seen at the public abattoirs, as the owner would scarcely care to pay freight etc. for an animal with the almost certainty of having the carcase rejected for human consumption.

As the question of the determination of the exact nature of the condition, whether merely one of chronic inflammation, or whether the popular term "Cancer" was a scientifically correct one, was a matter of economic importance both from a meat inspection as well as a therapeutic point of view, the writer was invited by the Chief Inspector of Stock, during 1921-22, to make an examination of such affected sheeps' ears as could be obtained, in order to ascertain the nature of the lesions. Up to the time of writing, forty-seven ears from the same number of sheep and from various localities, have been examined histologically, and it is felt that sufficient examples of the condition have been collected to justify one drawing conclusions that may have some value.

A few of the cases, nine, were evidently of fairly recent origin, but the majority, viz. thirty-two, were clinically cancerous and six were intermediate. In no instance was a history of the case sent with the specimen, merely a note saying that it was a specimen of cancered ear from a sheep. Some were obtained from sheep in the field, others at the time of shearing. It is necessary to state that no conclusions from this work can be drawn as to the relative frequency of malignancy occurring in the so-called "cancer of the ear" in sheep as a whole. Since although stock inspectors and sheep owners were requested to forward ears in all stages of the condition, the sender almost always took pains to obtain what he considered a good specimen of cancered ear. This as a rule being one in an advanced stage.

The result of the microscopical examinations revealed the fact that nearly all the cases which might be termed advanced, showed more or less evidence of malignancy and that one was dealing with squamous celled carcinomata in different stages. The nine early cases showed nothing more than a chronic inflammatory reaction. Of the remaining thirty-eight cases, six, which may be termed intermediate, showed great hyperplasia of the cutaneous epithelium, with longer or shorter papillary processes dipping down into the underlying structures, but no evidence of breaking away or unrestrained growth. Thirty-two were distinctly epitheliomatous. As the examination proceeded it became evident that the matter had assumed a more general importance, since there appeared to be a definite answer to the question "Does chronic irritation in the case of the lower animals, ever lead to cancer formation?"

As already noted, no history was supplied with any of the specimens as to when and how the condition arose. It is only in isolated instances that it is possible to obtain a history in the case of sheep running in large paddocks, since attention is only attracted to the ear when it is exhibiting very visible changes, *i.e.* the condition has become well established. The early cases are as a rule only noticed when the sheep are actually being handled, as in shearing. Speaking generally however, from one's own observations in the field and the information collected from others, one can obtain a fairly complete clinical picture, and by the examination of a number of sections from each of the forty-seven cases, one is able to construct a picture of the changes undergone by an affected ear from that of ordinary local chronic inflammation to that of very obvious malignancy. Finally, as will be seen, I was able to obtain a live sheep affected with "cancer of the ear," and by keeping it under observation, was able to follow the clinical course of events of malignancy until metastasis had become well established.

Clinical features and naked eye characters.

Most of the specimens examined have been from adult sheep, but the condition is not confined exclusively to them; I have not however seen young lambs affected. Speaking generally, it may be stated that the actual starting point of the condition is either a wound or local necrosis. Most cases apparently commencing at the tip or around the free edge of the auricula. At times the point of origin appears to be an ear mark.[1] At others the origin appears to be necrosis of the tip of the ear, the latter condition being commonly seen in sheep in Australia, and is due to a variety of causes.

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[1] Portions of the ear of varying shapes are removed from the edge at different parts for the purpose of identifying sheep of any particular

Undoubtedly, the vast majority of wounds inflicted on the ear, no matter by what agency, never pass beyond the stage of inflammation, acute or chronic, although many of them become secondarily infected with various organisms. Sometimes this secondary infection together with the constant irritation by flies etc., induces a low grade inflammation of the part. This inflammation is constantly being stimulated by the agencies mentioned, aided by the further injuries inflicted on the ear by the animal itself in its endeavours to allay the irritation or to shake off offending insects. Thus there is presented a very varying picture according to the length of time the condition has been in existence and to what extent secondary factors have been acting.

In the case of the forty-seven ears examined, the very early lesions would naturally, in practice, be included among those that never pass beyond the ordinary stages of inflammation or necrosis and of course it is impossible to foretell what would have happened to those particular ears had their possessors been allowed to live. In the case of the ears showing simple inflammation, the lesion presented the ordinary characters of a wound healing under scab. Where necrosis was the origin, the necrosed portion of the ear varied in extent. Sometimes the necrosed portion ran along the edge of the auricula for several inches but did not extend inwardly very far, the affected part having a dried, withered up appearance.

The necrotic part and the adjacent tissues may become damaged from various causes and then the latter becomes inflamed. Secondary factors already indicated come into action and then the lesion, whether originating in a wound or from simple necrosis, becomes very much the same in all cases. Ears examined at a later stage show evidence of chronic inflammation. The affected area has extended. The part is covered with a thick crust of scab and on lifting this, granulation tissue may be seen underneath. There is usually a little exudate present, at times yellowish, at others purulent.

At an advanced stage, the clinical changes are very pronounced. The affected ear is swollen, at times so much that the meatus is obliterated. The swelling may extend for some distance around the base of the ear. The skin is firmly adherent to the underlying tissues. The tip of the ear is represented by a blackened mass often larger than a man's hand, with many fissures in it from which oozes an exudate often purulent and at times mixed with blood. Some of these lesions are of the cauliflower type in appearance. Not infrequently fly larvæ may be found in the fissures. If the scab, which at times appears like an ordinary blood clot and at others has a caseous crumbling character, is lifted, a granulation-like tissue is seen underneath with ulcerating edges, the latter being elevated and firm. The naked eye appearances are often complicated by injuries inflicted on the ear by the animal in its endeavour to allay irritation or to shake off offending insects. The extent and character of the lesion itself and the degree to which the adjacent tissue of the ear participates varies with each individual case and depends on the length of time the condition has existed and the injuries inflicted by the animal itself, or other agencies. In the final stages the animal becomes thin and cachectic. The wool is ragged and readily pulled out.

In the majority of advanced cases the whole of the new growth cuts very firmly on section, sometimes like tendon. These latter appear to be the cases were keratinization is very extensive, rather than to a great excess of stroma.

The cut surface is of a dirty greyish-white colour except at the ulcerating edge, with small islands or strands of a lighter colour (epithelium) scattered throughout more or less abundantly. Occasionally with the scirrhous growths, after removal of the skin, portions may be flaked off, somewhat like the layers of an onion. Central softening has been observed in one case, the part having a caseous character. No tubercle or other bacilli could be demonstrated in the softened material.

Histology.

Sections of ears examined in the early stages present merely a picture of subacute or chronic inflammation. The epithelium where present, showing little or no alteration. In the longer standing cases more pronounced changes are evident. The scab mass is thicker. Underneath this is a mass of granulated tissue, whilst deeper still is a varying amouut of fibrous tissue, more or less fully formed. At the edge of the ulcer and for some distance away from it, the epithelium has undergone great hyperplasia. The layer being of considerable thickness, with finger-like processes dipping down for varying distances into the underlying tissues. There is however at this stage, no sign of malignancy, *i.e.* the epithelium, although greatly overgrown, shows no sign of breaking away and assuming independent growth. In the advanced cases the changes in the auricula are pronounced, the epithelium, which is of the stratified, squamous variety, can at the extremity of the finger-like processes be seen rapidly invading the subjacent structures. In others the epithelium has broken away from the parent body and has assumed quite independent growth. The auricula is greatly thickened, the conchal cartilage being normal. The tissues external to the concha [are more implicated than those of the internal surface. The edge of the lesion, *i.e.* that corresponding to the ulcerated surface, is seen to be composed of more or less young fibrous tissue. Deeper down, the normal tissue has been replaced by epithelium and stroma. The epithelium varies very considerably. In the early stages of malignancy, the invading epithelium is not abundant, if one excepts the large down-growing papillæ from the surface. There are many signs of reaction on the part of the tissues in the form of numerous fibro-blasts around the young growing and infiltrating epithelium. More or fewer mono- and polymorpho-nuclear lecocytes are present near the ulcerated area, indicating secondary infection. The epithelial cells, which are the spinous cells from the malpighian layer are at first normal, but as the condition persists and the epithelium extends its field of growth, there is often considerable change in the cells. This being more frequently in the direction of size. Distortion of epithelial cells is rather common, especially at the edges of the young growing epithelium. This is quite apart from those cells forming epithelial pearls and undergoing hornification. Giant cells varying in size and the number of their nuclei have been seen in sections from some cases.

Keratinization appears to set in early. Even in some cases, where it was evident microscopically that malignancy had only been recently established, there was distinct evidence of pearl nest formation. In cases where the epitheliomatous condition had become the dominant one in the section, keratinization was very pronounced. At times the whole of a section has been composed of keratinized epithelium.

The stroma also varies very considerably both in age and amount. At the apices of the young, burrowing epithelial strands are fibroblasts, sometimes scanty and at others abundant. No doubt this variation in amount is due to the varying activity in growth of the epithelium.

Usually in this situation too are a number of leucocytes. In other places the stroma has the form of a spindle celled tissue. In older situations, fully formed fibrous tissue is present. The proportion of stroma to epithelium also varies very greatly. In places the former is abundant and the epithelial islands or strands scanty and small. In other situations the stroma is negligible, whilst enormous masses of stratified squamous epithelium with numerous "pearls" either discrete or confluent, dominate the picture. At times secondary changes due to bacteria tend to complicate the histological view around the ulcerating area of the primary lesion.

At the base of the ear in the cases where the burrowing epithelium has reached that locality, the picture becomes typically and purely carcinomatous. Secondary changes not having extended so deeply, the infiltration of the burrowing epithelium into the muscles of the ear, with their destruction, and the formation of the stroma of the neoplasm is striking.

A case of "cancer of the ear" in a sheep, accompanied by metastasis.

It having been ascertained that a large proportion of advanced cases of "cancer of the ear" of sheep were epitheliomatous, it became of interest to find out whether the malignancy was a local one, or whether metastasis occurred? It was evident that the information required could not be obtained from the sheep owner, since that would imply a knowledge of what metastasis was, and also a greater degree of observation of individual sheep than is usually given in Australia. The matter therefore resolved itself into one of personal observation. Consequently, through the Chief Inspector of Stock, I obtained a live sheep affected with "cancer of the ear" and kept it under daily observation until it was killed. During this period it was allowed to run at liberty in a small paddock with other sheep. The animal, aged about four years, was received on 10th March, 1922. The affected ear at that time showed a black looking scab mass about 3 × 2 inches in area, near the apex. The condition had evidently been existing some time. Indeed, the animal had been sent as a "good specimen." The tip of the ear had disappeared. On lifting the scab a slightly purulent, granulomatous mass was exposed, with ulcerating edges. The auricula was moderately swollen and slightly thickened near the lesion. The skin was attached firmly to the underlying tissues. No treatment was attempted.

During the succeeding three months viz. March, April and May, there was very little change in the appearance of the affected ear, save that the scab mass became a little larger, the thickening of the skin around the lesion more pronounced, and there appeared to be a greater tendency for the part to bleed through the animal's own actions. Appetite and condition were maintained, and there did not appear to be any great pain.

In June (four months later) the whole of the auricula had become swollen and the granulating mass at what had been the apex, much more extensive (about 4×4 inches), ulceration at the borders of this mass being pronounced. The edges were indurated. Bleeding from the part occurred very readily on manipulation.

In July the ulcerated area had increased. The base of the ear had also become involved in the swelling. Bleeding occurred even when the animal shook its head to obtain relief from flies. Although appetite and condition were unchanged, the animal appeared less active than usual and showed some evidence of pain in the affected ear.

August 5th (5 months later) the affected ear had now assumed a repulsive appearance, and the growth was clinically of a malignant character. There was a large cauliflower-like mass, somewhat larger than the size of a man's fist, bleeding very readily. Fissures of varying depth covered the surface of the growth, a considerable amount of exudate coming from them, at places somewhat purulent. The whole of the auricula was very swollen, the entrance to the external ear being almost occluded. The skin was firmly attached to the underlying tissues. The scab itself had assumed a more caseous or crumbling character, portions coming away very readily on manipulation. The ulceration had made more rapid progress. The animal's appetite still remained good, but it was rapidly losing condition and the wool was commencing to fall out, leaving bare patches (cachexia). Flies were continually ovipositing on the ulcerated surface, and both the eggs and the larvæ were difficult to remove from the deep fissures. They added to the animal's distress.

On this date the (unnamed) cervical lymphatic gland on the same side, which lies about midway between the atlantis bone and the point of the shoulder, showed signs of enlargement, being now about the size of a small cherry; it was also very hard and painless. The thick mat of wool on the animal prevented earlier recognition of the enlargement of the gland. This gland increased in size with great rapidity. In fact one could almost see a change every day, until August 20th, it had reached the size of a golf ball. It was quite circumscribed, very hard on palpation with no evidence of softening anywhere. There were no clinical signs of inflammation either of the gland or of the surrounding tissues, if one excepts the enlargement. The skin over the gland was intact.

September 20th, the sheep was killed this day for humanitarian reasons. The distress caused by the "fly-blown" condition of the ear was great. It being impossible to keep flies away or prevent them depositing their eggs in the fissures of the ulcerating growth. In addition to this the greatly distorted auricula, with its black cauliflower-like mass at the end, hung down the side of the animal's face, and blood and exudate were constantly dripping down the latter. Appetite had been lost and the animal stood dejectedly in the paddock making little attempt to move. The fleece had become so ragged and removed in patches, that the animal had the appearance of a scabied sheep.

Autopsy.

Animal in very poor condition. Skin bare in patches. The wool in general very ragged and easily pulled out. The affected ear was almost hidden under a mass of what looked like scab and granulation tissue. This mass was about 4×5 inches in diameter. Deep fissures ran through it in all directions. From these exuded a blood-tinged exudate. Many fly larvæ were found at the bottom of the fissures. At the edges of this mass the skin was ulcerated and indurated. The rest of the auricula was so swollen and indurated that it had more of a solid cylindrical appearance than of its characteristic shape. The external meatus was practically occluded. The skin of the ear was firmly adherent to the subjacent parts. This thickening, induration and adherence of the skin extended for an inch or so around and from the base of the ear.

The unnamed cervical lymphatic gland was enlarged to about the size of a tennis ball and very firm. The skin over the gland had ruptured in one or two places. The gland cut more like soft horn. On section the cut surface was of a greyish-white colour and had a granular appearance. Near the centre was a rather caseous area about half an inch in diameter. There was no sign of inflammation.

The prescapular gland on the same side was enlarged to about the size of a walnut and on palpation, several hard, nodular areas, about the size of a garden pea were felt. No other lesions were seen.

Histology.

Sections taken from various parts of the ear showed a very similar histology, viz., large masses of stratified epithelium and a rather scanty fibrous stroma. In some sections, the whole mass had undergone hornification resulting from the fusion of large individual "pearl nests." The masses were heavily impregnated with eleidin. In such sections, the fibrsus stroma was practically absent. At the base of the ear, the condition was not in such an advanced stage, the whole of the original structures having not been entirely destroyed. Sections showed numerous strands, small islands and larger masses of stratified squamous epithelium, some of the later commencing to undergo keratinization, burrowing in a rather scanty stroma. In places the latter was not fully formed and was represented by fibroblasts and spindle cells at the apices of the epithelial strands. In these situations also, a few leucocytes were present. Remains of the normal structures, such as muscle etc. could be seen here and there. There was considerable departure from the normal epithelium. A few giant cells were present.

The secondary growth (Cervical lymphatic gland). In this gland, practically the whole of the new growth had undergone hornification. Occasionally some of the keratinized masses were bordered by two or three layers of stratified squamous epithelium, with rather large cells. There was very little young, active epithelium present. The fibrous stroma was scanty. No traces of the normal gland substance could be seen, the caseous material in the softened area contained numerous desquamated epithelial cells but no bacteria.

The tertiary growth (Prescapular lymphatic gland). Some parts of the gland were normal, but in others small islands and fine strands of stratified squamous epithelium were present, surrounded by a stroma of young fibrous connective tissue. The epithelium was apparently very active and was infiltrating and destroying the gland substance in its neighbourhood.

In the foregoing case it was impossible to say how long the condition had existed before malignancy set in. Judging from other examples, one can say that it must have been existing months if not years, purely as a chronic inflammatory lesion. It is however, probable that the growth had already assumed malignant characters when the animal was received in March. It was under observation for a period of about six months. It is of interest to note that although the primary growth increased steadily from the time it first came under observation, no metastasis was seen until August 1st, but once that was established progress was rapid. Within twenty days the secondary growth had reached the size of a golf ball. In fifty-two days it was as large as a tennis ball, and metastasis was well advanced in the next lymphatic gland, viz. the prescapular.

With regard to the condition of the secondary growth, viz. in the cervical lymphatic gland, keratinization is looked upon by some pathologists as evidence of recovery. But in this case, even if the growth in the cervical gland were no longer active, it is evident that it was too late to be of any benefit to the affected animal, since metastasis had already occurred in the next or prescapular gland.

Attempts to transfer the growth by implanting fragments about the size of a lentil from the secondary tumour (cervical gland) failed. In two instances the graft took temporarily, gradually increasing in size to that of a large walnut, then they slowly retrogressed and finally disappeared. The transplanted growths were spherical, very firm, painless and quite circumscribed. Unfortunately, no tissue was removed from these grafts for histological examination, owing to the fear of setting up secondary inflammatory changes. No very great value can be attached to the results of this transmission experiment, since an insufficient number of sheep were used, and the histology of the secondary growth that was employed, showed subsequently that on account of extensive keratinization, the material was not suitable for grafting.

Remarks.

Sheep in Australia frequently receive injuries to an ear from various causes, *e.g.* by ear marking, or the necrosis due to a variety of factors. Undoubtedly in the great majority of cases, such injuries never result in more than a passing inflammation of the surrounding tissues. In a certain number, however, the part from a variety of causes becomes chronically inflamed, and in some of these, the exact proportion being unknown, the continued irritation and stimulation of the epithelium arouses unrestrained growth of the latter and a typical epithelioma results. Thus the popular term "cancer of the ear" for this condition in sheep is justified in some cases but not in all. The chronically inflamed condition may and probably does exist for a relatively long period as such, but once malignancy has set in the progress is rapid. Whether the malignancy would remain local in most of the cases where it had become established, or whether all cases would become metastatic if left to themselves, is difficult to say since sheep badly affected with "cancer of the ear" are usually killed when they come under observation in the field, but the case cited in detail shows that metastasis can and does occur if the animal is allowed to live long enough.

From a therapeutic point of view, it is evident that proper treatment of injuries to the ear would result in their stopping as cases of simple inflammation, but such individual treatment, merely to prevent something that might or might not occur at some such later date, is not one that would appeal to the average sheep owner in Australia. It is also quite possible that early cases of malignancy could be dealt with by amputation of the affected ear, but unfortunanely, in New South Wales at least, removal of a sheep's ear is forbidden by law, since it would destroy evidence in the shape of the ear mark of ownership. It might be argued that such evidence in a case of "cancer of the ear," is already obliterated; this is true, but the statement that the ear had been removed because of cancer might be readily made use of by an individual in unlawful possession of sheep.

From a meat inspection point of view, action would depend upon whether the malignancy was local, or whether the growth had become metastatic and also on the general condition of the animal.

The work has also shown that naturally acquired cancer arising from long standing irritation can and does occur in the lower animals and that the skin of the ear of sheep is one of the vulnerable sites for epithelioma formation.

THE ESTIMATION OF CINEOL IN ESSENTIAL OILS BY THE "COCKING" PROCESS.

By L. S. CASH, B.Sc., and C. E. FAWSITT, D.Sc.

[*Read before the Royal Society of N.S. Wales, August 1, 1923.*]

THE newest method of estimating cineol as introduced by Cocking[1] consists in mixing 3 grams of the oil with 2·1 grams of o-cresol and then determining the freezing point of this mixture. The authors have tried from time to time the various methods of estimating cineol in eucalyptus oil, viz. the "Scammell" phosphoric acid method as improved by Smith[2] and the resorcinol method. There is less difficulty to the novice in carrying out the Cocking method than the other methods, and it appears to be a method which gives results of greater accuracy than the others, provided the oil contains at least 65 per cent. of cineol.

If an oil is suspected of containing less than 60 per cent. of cineol, it should be mixed with an equal or greater weight of cineol before it is examined by the Cocking method. In the following experiments pure cineol was mixed with definite quantities of other constituents commonly occurring in eucalyptus oils, and 3 grams of this (artificial) oil were then mixed with 2·1 grams of o-cresol in the usual way. The freezing points obtained are given below. Along with these figures are given figures for the density of the oils, also the viscosity of the oils compared with water taken as unity.

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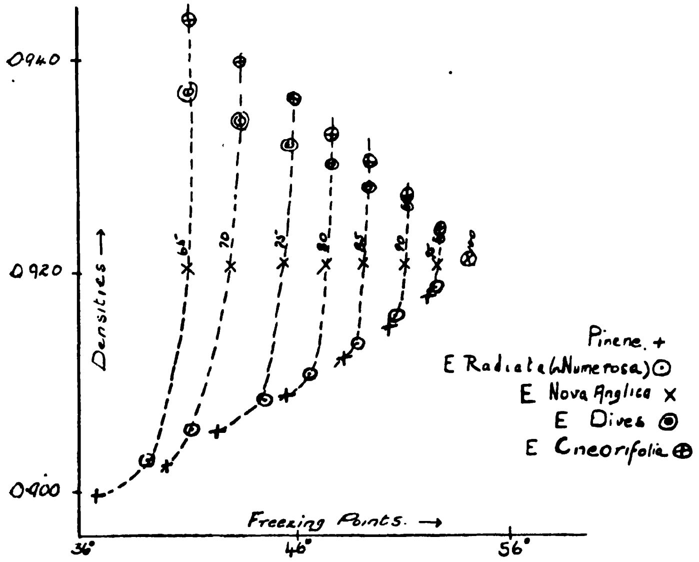
[1] Pharmacy Year Book, 1920, p. 395.

[2] Baker and Smith, "Eucalypts and their Essential Oils," 2nd Edition, 1920.

Addition to Cineol.	Percentage of Cineol.	Freezing Point.	Density. 25°/4°	Vicosity. 25°
0	100	54·2° C.	0·920	2·80
Crude oil of *Eucalyptus radiata* containing originally no cineol.	95	52·7	0·917	3·14
	90	50·5	0·914	...
	85	49·0	0·912	...
	80	46·9	0·910	4·36
	75	44·6	0·907	5·06
	70	41·1	0·905	5·88
	65	39·2	0·902	...
Pinene.	95	52·4	0·917	2·74
	90	50·8	0·914	...
	85	48·4	0·911	2·66
	80	45·6	0·908	...
	75	42·4	0·905	2·37
	70	40·0	0·902	...
	65	36·5	0·899	...
Crude oil of *Eucalyptus dives.*	95	53·0	0·922	3·01
	90	51·7	0·924	...
	85	49·8	0·927	3·43
	80	48·1	0·929	3·66
	75	46·0	0·931	4·00
	70	44·1	0·933	4·27
	65	41·6	0·936	...
High Boiling-Point Residues from the oil of *Eucalyptus cneorifolia.*	95	53·2	0·923	...
	90	51·5	0·926	3·43
	85	49·9	0·929	3·81
	80	47·8	0·932	...
	75	46·6	0·935	4·53
	70	43·9	0·939	...
	65	41·5	0·943	5·71
Crude oil of *Eucalyptus nova anglica.*	95	52·8	0·920	...
	90	51·4	0·920	3·10
	85	49·4	0·920	...
	80	47·6	0·920	3·40
	75	45·4	0·920	3·65
	70	43·2	0·920	3·85
	65	41·2	0·920	...



It was hoped that if the freezing points for mixtures containing equal amounts of cineol were plotted against either the densities or viscosities of these mixtures, then the percentage of cineol in an unknown mixture could be calculated more exactly than from the freezing point determination alone. In this regard the densities give better results than the viscosities and the curve shown has the freezing points plotted as abscissæ and the densities as ordinates. It will be noticed that some mixtures containing a certain percentage of cineol freeze at a lower temperature than others. This difference may amount in extreme cases to 5° C. Those mixtures which freeze at lower temperatures have however lower densities, so that the percentage of cineol in an oil should be capable of estimation with a maximum error of 2%.

We desire to thank Mr. C. H. Fischer for carrying out some of the experimental work of this paper, and Mr. A. R. Penfold for giving us some oils used in the work.

INVESTIGATIONS BY THE LATE C. O. HAMBLIN INTO THE HELMINTHOSPORIUM DISEASE OF WHEAT.

By H. J. HYNES, B.Sc. Agr.,

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With Plate X.

[*Read before the Royal Society of N.S. Wales, August 1, 1923.*]

IN January 1922,(1) Mr. Charles O. Hamblin, B.Sc., B.Sc., Agr., late Principal Assistant Biologist in the New South Wales Department of Agriculture, drew attention to a serious disease in wheat, the cause of which he attributed to a fungus belonging to the genus Helminthosporium. This article is written in semi-popular style and gives a brief account of the history of the disease, the outstanding differences from those caused by "Take All" (Ophiobolus), and recommendations for control. This is the first publication dealing with the Helminthosporium "Foot Rot" of wheat in Australia.

At the time of his lamented death on the 1st October, 1922, Mr. Hamblin had work in hand relating to Helminthosporium which was of rather technical interest. With a view of making available to scientific workers the nature of this work Mr. Hamblin's original manuscripts have been examined and revised and put into form for publication.

This paper, then, brings up-to-date our knowledge of the Helminthosporium "Foot Rot" of wheat so far as investigations in New South Wales are concerned.

The Helminthosporium wheat disease in U.S.A.

In the United States there are two "Foot Rot" conditions in wheat attributed to Helminthosporium.

In the States of Illinois and Indiana a disease referred to as "Take All" (now known to be distinct from our Australian "Take All") has been found present on wheat.(2) The symptoms of this disease are, in addition to the basal browning and rotting of the stems, a very pronounced dwarfing and "bunchy" appearance in the early stages of the plants' growth, due to the excessive number of spring tillers which develop in affected plants. Dr. F. L. Stevens (3) and (4) of Illinois has shown that Helminthosporium is a true parasite of wheat capable of producing a "Foot Rot" condition in that state. McKinney, however, points out(5) that the form of Helminthosporium found associated with "Foot Rot" plants in Illinois has not yet produced the characteristic field symptoms of the so-called "Take All" reported from that state. He further states that "there is a suggestion that the so-called "Take All" in Illinois and Indiana may be an unusual manifestation of the Helminthosporium disease of wheat present in many sections of the States . . . . further work is necessary before the cause of this disease can be definitely assigned to this organism." McKinney proposes to substitute the name "Wheat Rosette" for the Illinois "Take All" condition.

In addition to the Illinois "Take All" there is the Helminthosporium disease of wheat, widely spread throughout the United States, which formed the subject of investigation by Mrs. L. J. Stakman at Minnesota.(6) In her publication she points out that whilst the Helminthosporium "Foot Rot" resembles somewhat the Illinois "Take All" yet there are certain differences and it cannot be stated that the two diseases are identical.

A point of interest here is that varieties of wheat like Turkey Red, Early May and Red Wave which are immune to Illinois "Take All" are distinctly susceptible to the Helminthosporium disease present in Minnesota and other parts.

Mr. Hamblin was consequently anxious to determine exactly the identity of the local strain of Helminthosporium and its relationship to the types isolated in the United States. Type cultures were forwarded to English and American workers for comparison. From extensive correspondence with workers abroad Mr. Hamblin was led to believe that the Australian Helminthosporium was very probably similar to the *H. sativum* described by Mrs. Stakman from Minnesota. Mr. R. J. Noble writing to Mr. Hamblin from Minnesota on November 28th, 1921, regarding the Australian strain, states "the culture brought over is apparently *H. sativum*, the temperature range varying from 0 to 35° C. with an optimum temperature of 25 to 28° C. It is known to attack all cereals and 70 varieties of grasses."

Dr. F. L. Stevens also examined a culture of our Australian Helminthosporium. He states "while it is similar to the one I find here it differs somewhat. In particular the spores are shorter, thicker, more nearly oblong, less tapering. It is apparently a different sub-species or race at least."

Mr. Hamblin examined a culture of Helminthosporium forwarded from Mr. R. E. Massey, Government Botanist of the Sudan, and found that it closely resembled the Australian form.

It appears that further investigation is needed to confirm the opinion that our Australian Helminthosporium is identical with the Minnesota form.

Studies on the Morphology of the Fungus.

The strain of Helminthosporium isolated was readily grown in culture on glucose agar and on corn meal agar. Mr. W. L. Waterhouse of the Sydney University recommended potato dextrose agar as being an excellent general culture medium; this was tried and found to be so successful that it was then exclusively used.

On this medium the growth of the fungus was found to be whitish in appearance for the first two days, changing to greenish-grey and finally to black in the centre by the fourth day when spores were freely produced. It was observed that the fungus growth, which was more rapid at a temperature of 25 to 26° C. than at 32° C., was more or less tabular and flat, though the spores are to some extent borne on erect hyphæ.

The mycelium is hyaline to olive-brown or yellow-brown in colour, whilst the spores are mostly of an olive-brown tinge. The spores produced in culture were found to be very variable in size, shape and septation. Measurements of spores taken direct from diseased wheat plants indicated that they varied from 75 to 110μ in length by 10 to 18μ in breadth, with the maximum breadth usually toward the basal part of the spore. The ends of the spores are rather sharply rounded, occasionally unequal. The number of septa ranged from 1 to 11; some spores showed no septation; Y-shaped spores mentioned by Stevens(4) were fairly commonly found in culture. The type of spore isolated from plants of *Bromus inermis* and spear grass affected with Foot Rot was of the same general character as that from wheat. In one instance a small spore type of Helminthosporium (about 16·8μ long, pale brown) was isolated from Canberra wheat; this type was also found on *Bromus inermis* in addition to the large ones mentioned above.

Studies in Pathogenicity.

Mr. Hamblin, as Principal Assistant to Dr. G. P. Darnell-Smith, Government Biologist, was actively engaged during his three year term of office in the general plant pathological work of the State Department of Agriculture. This short period together with the routine work involved did not permit Mr. Hamblin to proceed very far in his research on the "Foot Rot" problem; it is certain that his work in this connection would have been of a very high order had he been spared to carry out his investigations still further. He was, however, the first in Australia to prove that Helminthosporium was a potential parasite of the wheat plant. His work in this connection is borne out by his experiments, details of which are given as follows:—

Demonstration of the parasitic nature of the fungus Helminthosporium.

Twelve 4 inch pots containing good loamy soil were sterilized in the autoclave for 1 hour at a temperature of 115° C. On the 10/12/21, each of six pots were then inoculated with one tube culture of the strain of Helminthosporium obtained from a Cowra wheat (Marshall's No. 3) in November 1920. The other six pots were treated as controls.

All pots were then placed on earthenware crocks and each was covered with a pad of dry filter paper. The pots were watered at time of inoculation and thereafter at various intervals. On 29/12/21 there was evidence of mycelial growth on the soil of all six inoculated pots, whitish to brown in colour. On 7/1/22 pots were watered and seed of Hard Federation wheat obtained from Cowra Experiment Farm was sown, three seeds per pot:—

	Controls.		*Inoculated Soil.*
1 2 3	Seed untreated.	7 8 9	Seed untreated.
4 5 6	Seed sterilized in $HgCl_2$ (1 in 1000) for 15 min.; washed in sterile water; sown wet.	10 11 12	Seed sterilized in $HgCl_2$ (1 in 1000) for 15 min; washed in sterile water; sown wet.

By 9/1/22 all seeds had germinated with the exception of one in pot 10. The seedlings were watered frequently.

On 25/1/22 all the plants grown in inoculated soil (pots 7–12) showed tobacco coloured butts which indicated infection from Helminthosporium.

By 1/2/22 all the infected plants were dead. Mycelium and conidia of the fungus Helminthosporium were found on the plants in great abundance. Reisolation cultures were made.

The control plants remained healthy for a fortnight beyond this stage when the experiment terminated. The treatment of the seed with $HgCl_2$ could not of course prevent the infection of the plants so treated. The fact, however, that these, equally with the untreated, developed the disease when the inoculum was added, shows that the added material was the infecting agent and that it was not resident in the seed experimented with.

The conclusion which Mr. Hamblin draws from this experiment is that the strain of Helminthosporium isolated from Cowra wheat is capable of producing the "Foot Rot" disease in Hard Federation wheat and of killing the plants so infected when the soil is kept in a damp condition. This fungus must therefore be regarded as a true parasite under moist soil conditions.

The Production of leaf-lesions.

On 16/2/22 three 4 inch pots were taken in each of which 3 healthy plants of Hard Federation wheat were growing.

Pot 1 was placed under a bell-jar and sprayed by means of an atomiser with a suspension of Helminthosporium conidia and mycelial fragments in sterile water, using the same strain as in last experiment.

Pot 2 was similarly treated with water only to serve as a control.

Pot 3 was treated in the same manner as Pot 1.

Pots 1 and 2 were allowed to remain under bell jars in a well lighted position in a room while No. 3 was placed in a similarly well lighted room.

On 21/2/22 the following observations were made:—

Pot 1. Narrow dark brown necrotic lesions occurred on the leaves of one plant, ranging from $\frac{1}{8}$ to $\frac{1}{4}$ inch in length. Similar lesions occurred on the other two plants near the base where the lowest leaf joined the leaf sheath.

The plants in Pot 2 were healthy.

In Pot 3 dark brown lesions, slightly yellow at the margins, occurred on the leaves of the three plants, ranging from $\frac{1}{16}$ to $\frac{1}{8}$ inch in length.

Conidia of the fungus were found on the lesions in great abundance. Tissue plantings gave typical cultures of Helminthosporium.

On 21/3/22 the plants had been left in pots under the bell-jars for a month, and in the case of pots 1 and 3 they finally died. On these dead plants Helminthosporium was found in abundance. In the case of Pot No. 2 (control) the three plants were fairly healthy. Spores of *Alternaria* were found on dead leaves.

Mr. Hamblin concludes, then, that with the humid conditions created under a bell-jar the Helminthosporium isolated from Cowra wheat can produce leaf lesions on Hard Federation wheat. This conclusion is important because of the parallel with the symptoms of secondary infection (leaf lesions) recorded by Mrs. Stakman(6); these Mr. Hamblin had not observed in the field.

A second method of inoculating leaves with Helminthosporium.

In this experiment two pots each containing three plants of Hard Federation wheat were used. (Pots labelled 1 and 2). All plants looked equally healthy and had made equivalent growth.

On 16/2/22, on the plants in Pot No. 1 four leaf punctures (up to $\frac{1}{4}$ inch in length), two per plant, were made with a sterile needle. Portion of a culture of the strain of Helminthosporium used in the foregoing experiments was then added to each puncture. One leaf on the third plant was painted with sterile water and then a portion of the culture added with a sterile flat knife without injuring the leaf. The plants were watered and the pot placed under a bell-jar.

Pot No. 2 acted as a control; four leaf punctures, two per plant, were made as before but no inoculum was added. One leaf on the remaining plant was painted with sterile water—no inoculum was added.

On 20/2/22, plants in pot No. 1 were examined. In the case of plants 1 and 2, leaf lesions were apparent with browning and death of the tissue at one of the punctures; on the other no injury was evident. The remaining plant (No. 3), where spores had been laid on leaf with flat knife, showed no signs of infection.

By 21/2/22 on plant 1 the lesion had extended across the whole blade of the leaf in one case, while on plant 2 the lesion occupied only about half this area. No development on other spots was observed.

On 20/2/22 plants in Pot No. 2 were examined. It was found that no growth of the fungus had taken place at leaf punctures or on leaf painted with sterile water. The punctures, moreover, did not cause the leaf to die as in Pot 1.

On 21/3/22 the whole of the leaves of plants in Pot 1 were affected and browned. Helminthosporium was produced in abundance on these leaves. In case of plants in Pot 2, no Helminthosporium was found but a small amount of the saprophyte *Epicoccum* was detected.

The conclusion drawn is that infection with Helminthosporium can be produced by puncture and inoculation with the conidia and mycelium, but the result is not surprising in view of results obtained in the foregoing experiments.

Infection and Seed Transmission of the Disease.

In 1921 Mr. W. L. Waterhouse made available to Mr. Hamblin space at the University plant house. Here seed from diseased plants submitted by Mr. J. T. Pridham early in the year was grown under controlled conditions. This gave rise to healthy plants in every case discounting the idea that the disease is seed borne. Evidence on this point Mr. Hamblin did not regard as conclusive. Lack of facilities did not allow him to further pursue the question of the way in which infection normally occurs. His observations, however, led him to say "there is every indication that it is either by adhesion to the seed or by mycelial infection through the soil; however, it may take place by both methods."

Occurrence of the disease on wheats and other hosts.

The occurrence of Helminthosporium was noted on plants other than wheat at the Cowra Experiment Farm in December 1921. Spores of the fungus were found abundantly on a crop of Slav Rye, showing a "Foot Rot" condition very similar to that on wheat; spores were also found on Skinless Barley, Barley Grass *(Hordeum murinum)*, *Bromus inermis*, *B. sterilis*, and Spear Grass. At Cowra Experiment Farm in 1921 Mr. Hamblin in company with Mr. J. P. Shelton examined a large number of wheat varieties growing in the breeding plots to determine whether Foot Rot was present. The following is a list of all varieties which were determined as infected, based on field examination; varieties on which conidia of Helminthosporium were actually determined by microscopic examination are denoted by an asterisk.

Triticum vulgare.

Allora Spring
Alpha
American 8 (not serious)
Anvil (bad)
Argentine
Aurora

Triticum vulgare—continued.

A. 88 (bad)
Baroota Wonder
Basil (not serious)
Bathurst No. 7
Bathurst No. 17
Bayah
Biffen's Red Fife (bad)
Biffen's White Fife
Biffen's 60/9
Biffen's 60/14
Billy Hughes
Blount's Lambrigg
Blue Wave
Bobs (Fusarium probably also present)
Bomen (bad)
Bonus
Booran
Bunge
Bunyip
*Canberra
Carrabin (not bad)
Cedar
*Clarendon
College Eclipse (poor)
College Purple (fair)
Comeback
Cormie's No. 3
Correll's No. 8
Currawa
Currawa (early crossback 53, from)
Darts Imperial (probably Fusarium also present)
Dawson's Golden Chaff
Dindiloa
Early Lambrigg
Early Red Chief
Eden (bad)
Etawah (bad)
Farmer's Friend
Fenman
*Federation (bad)
*Firbank
Florence
Forelock
Gluyas
*Gluyas (Bearded)
Golden Drop
*Gresley
*Hard Federation
Heywood's
Hoof's Imperial (very bad)
Hornblende
Hudson's Early Purple Straw
Indian King
John Brown (not serious)
Jonathan
Kanred (fair)
Keswycke
Kharkov
King's Red
King's White
Kota (fair)
Little Joss
Lott's White
Magenis
Majestic
Major (bad)
Major × Yandilla (fair)

Triticum vulgare—continued.

Marshall's No. 3 (bad)
Marquis (bad)
Merredin
Minister
Nangeenan
Narrogin
Narrogin No. 7
Narrogin No. 9
Nungarin
No. 24 (very bad)
No. 76 (bad)
Peace Hybrid
Penny (very bad)
Purple Straw (appears resistant)
Pusa 6
P. 1066
Rattling Jack
Red Glyndon
Red Skin
Red Wing (not serious)
Roseworthy
Rymer
Sanger's Prolific
Steinwedel
Sussex
S.H.J.
Talgai
Thew (very bad)
(Thew × Florence × Huguenot)[6]
Triumph
Turvey (fair)
Union 17
Union 28 (not serious)
Union 66
Vanessa
Wagga 8
Wagga 13
Wallace
*Wandilla
*Waratah
Warden (bad)
Warren (very bad)
(Warren x Florence x Huguenot)[6]
(Warren x Florence x Huguenot x Nyngan No. 2) (1 diseased).
(Warren x Nutcut)[7]
White Federation
Wickepin
Wilfred (very bad)
Wilhelmina (good appearance)
*Yandilla King (bad)
Yeoman C.
Zealand
Zealand Blue (bad)

Triticum durum.

Abyssinian
Acme
Algerian
Covelle
Huguenot (bad)
Kahle
Kubanka (not bad)
Marouani (fair)
Marouani (a strain)
Medeah (not bad)
Mindum (fair)
Speltz Marz (fair)

Triticum monococcum

*Einkorn (one plant seen)

Triticum dicoccum.

Emmer (Beardless)
Emmer (Blackwinter)
Emmer
Khapli

Triticum compactum.

American Club
Club
Clubhead
Little Club

Triticum spelta.

Black Bearded Spelt (apparently clean)
White Beardless Spelt

Triticum dicoccum-dicoccoides.

Synthetic Wild (bad)
Wild Common (bad)

In conclusion the writer desires to express to Mr. W. L. Waterhouse his thanks for very helpful criticism in the compilation of the matter; also to Messrs. J. T. Pridham and J. P. Shelton for assistance in classifying the varieties of wheat.

Summary.

1. The matter detailed in this paper is the work of the late Mr. C. O. Hamblin.

2. The strain of Helminthosporium isolated from Marshall's No. 3 wheat at Cowra Experiment Farm in November 1920 is probably identical with the type isolated by Mrs. Stakman from wheat at Minnesota.

3. The fungus which grows well on potato dextrose agar at a temperature of 25° C. is at first whitish in colour changing later to black with abundant spore production.

4. Spores taken direct from diseased plants range from 75 to 110μ by 10 to 18μ in size with from 1 to 11 septa; a small spore type (16·8μ) has also been found.

5. The strain of Helminthosporium isolated has been shown to be a parasite of the wheat plant in New South

Wales, capable of causing a "Foot Rot" condition and also causing secondary infection on the leaves.

6. Seed from diseased plants when sown gave rise to healthy plants. Infection probably occurs (1) by adhesion of spores to seed or (2) by mycelial infection through the the soil; probably in both ways.

7. In addition to wheat Helminthosporium spores have been observed on Slav Rye, Skinless Barley, *Hordeum murinum*, *Bromus inermis*, *B. sterilis*, and Spear Grass.

8. Field diagnosis of the "Foot Rot" condition indicates that the very large majority of wheat varieties grown or being tested locally are susceptible to attack.

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5. MCKINNEY, H. H.—"The so-called take-all disease of wheat in Illinois and Indiana," Abst. in Phytopath. 11 : 1, p. 37, 1921.
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Explanation of Plate X.

Photograph 1 and Photomicrograph 2 by W. J. Reay.

Fig. 1. Growth on potato dextrose agar of the Helminthosporium isolated from Marshall's No. 3 wheat.

Fig. 2. Spores of the same fungus taken from culture (× 145).

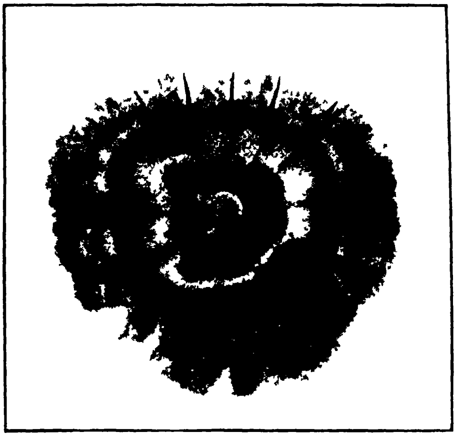

Fig. 1.

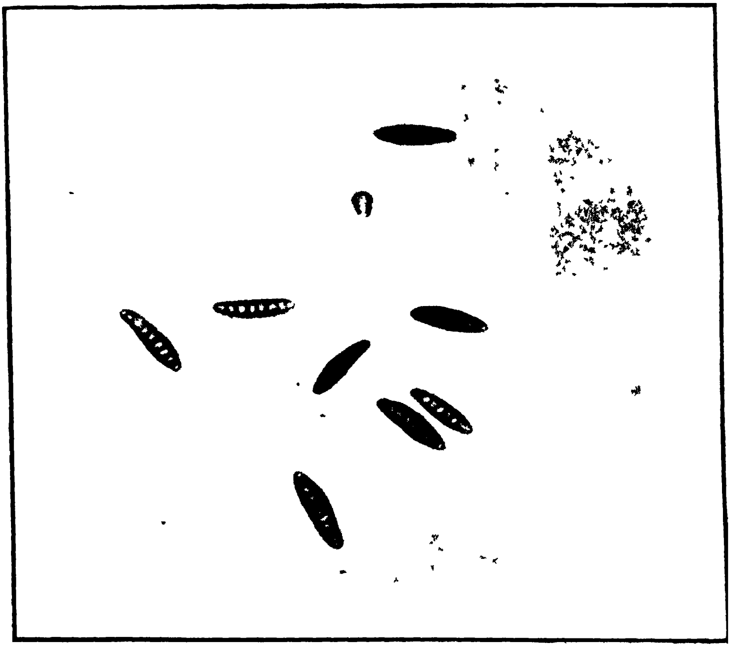

Fig. 2.

ATMOSPHERIC DUST AND ATMOSPHERIC IONISATION.

By EDGAR H. BOOTH, B.Sc.,

Lecturer in Physics in the University of Sydney.

[*Read before the Royal Society of N. S. Wales, September 5, 1923.*]

A VAST amount of work has been done in the investigation of atmospheric ionisation, the two main divisions being that dealing with dust free air, and that dealing with dusty air. With the first division the name of Wilson is most intimately associated, with the second division the name of Aitken.

Research in both branches has been carried out by many famous investigators, so that our knowledge of the subject to-day is deep. Yet many problems—even stated problems—remain to be solved. The author has spent much time from 1919 to 1922 in investigations into dusty air effects, which have led to some interesting results and conclusions in connection with the large ion, and also have considerable bearing on the discussion of the last few years on the types of ions produced by bubbling air through water.

Brief Resumé of Earlier Work.

The earliest work in connection with the subject that one can find is that of Coulier,[1] in which he discloses the fact that small, sudden diminutions in pressure on an enclosed volume of air result in the formation of fog, that the process repeated several times removes the cause of the fog, and that if the air be filtered through cotton wool, no fog results on subsequent small expansions. Attempts to "burn out" the nuclei led merely to increased fogs.

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[1] Coulier, Journal de Pharmacie et de Chimie, Vol. XXII, 1875.

Whilst this work was proceeding in France, John Aitken[1] was experimenting on similar lines in Scotland. He proceeded further than Coulier, and invented his 'dust counter,' by means of which he counted the number of particles present, insisting on the fact that the condensation nuclei were foreign to the air.

Kiessling[2] was unable to clear his air by repeated small expansions, or by filtration. The important point to observe is that he ensured saturation of the air by *bubbling* through water, which, in light of subsequent work, is sufficient to render all his results unintelligible.

R. von Helmholtz[3] attempted the further work of causing expansions of greater magnitude in dust-free air. According to his paper, the supersaturation produced should have been tenfold. No condensation ensued, a result quite contradicted by later experimenters, and showing that his expansions cannot have been adiabatic, and consequently his supersaturation was not so great as he had estimated.

A considerable amount of later work was then undertaken by Aitken,[4] and by Barus,[5] a consideration of which is not essential to this paper.

The Discovery of the Small Ion.

From now on the work of condensation on dust particles runs side by side with the discovery of the negative and positive small ion, and the increased activity in research on dust free air. C. T. R. Wilson, then Clerk-Maxwell student in the University of Cambridge, read his first paper on Atmospheric Ionisation before the Cambridge Philosophical Society, published in the "Proceedings of the Cambridge Philosophical Society," Vol. 8, 1895. This was really only an introductory paper—his next paper, read before the Royal Society, on April 8th, 1897, and published in "Philosophical Transactions," Vol. 189, entitled "Condensation of water vapour in the presence of dust free air and other gases," was far more comprehensive. In his first paper he announced his discovery that given an expansion of $\frac{V_2}{V_1} = 1{\cdot}25$ approximately, when V_1 and V_2 are the volumes of the air before and after expansion, condensation takes place sharply in dust free air. This corresponds to a fourfold supersaturation. [Aitken (Edin. Trans. 35) was able to remove all the dust particles from saturated air by repeatedly increasing the volume $\frac{1}{50}$ of the original amount —*i.e.* $\frac{V_2}{V_1} = 1{\cdot}02$.]

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[1] Aitken—"Trans. Roy. Soc. Edin.," Vol. 30 (1883), and Vol. 35 (1890).

[2] Kiessling—"Hamburger Abhandl der Naturwissenschaften," 1884.

[3] Helmholtz—"Wied. Annalen," Vol. 27 (1886).

[4] Aitken—"Trans. Roy. Soc. Edin." Vol. 36. "Proc. Roy. Soc., London," Vol. 5 (1892).

[5] Barus—"U.S. Dept. Agric., Weather Bureau," (1895). "Phil. Mag." Vol. 38 (1894). "Condensation of vapour as indicated by nuclei and ions," Carnegie Institute, Washington.

Wilson, commenting on this clearing expansion $\frac{V_2}{V_1} = 1{\cdot}02$, states "An even smaller expansion was found in these experiments to be sufficient for that purpose" . . . . "If after the dust has been removed in this way the successive expansions be made greater and greater, no visible effect is produced till $\frac{V_2}{V_1}$ . . . . . is equal to about 1·252."

In this paper Wilson finds, as previously noted, that unless the air were allowed to stand many hours the first expansion, however small, produced a fog. This repeated small expansion method was his first mode of "clearing" the air.

When $\frac{V_2}{V_1}$ exceeds 1·252, "a shower of drops is invariably produced." To see if these ions were produced spontaneously in the air, or were in the nature of dust particles, repeated filtering was tried, without, however, affecting the result. But we must observe "If, however, the air had to bubble through water on being driven back, quite a small expansion was sufficient to cause a shower, *even some minutes later.*"

In this paper, Wilson misses the positively charged ion, to be discovered later; he tries the effect of greater supersaturation, and finds that he passes to heavy fog when the expansion reaches 1·38. For the author's purpose it is necessary to draw attention here to Wilson's added note "When expansion results in a fog, it is of course necessary to get rid of all traces of it before proceeding to fresh observations. This was done by repeated expansions of moderate amount, as in the removal of dust particles."

Wilson[1] published several further papers in connection with condensation on the small ion before recognising that he was dealing solely with the negative small ion; this work was in connection with X Ray ionisation, and ionisation by active salts. He points out that the small ions must be of almost molecular dimensions.

Professor J. J. Thomson pointed out the necessity of investigating the relative condensing powers of negatively and positively charged ions, in his paper "On the charge of electricity carried by the ions produced by Rontgen rays" (Phil. Mag. Vol. 46, 1898) which led to further investigations by Wilson, and his paper in Philosophical Transactions, Vol. 193, "On the Comparative Efficiency as Condensation Nuclei of Positively and Negatively Charged Ions." Here we find the different supersaturation required for the positive small ion first recognised, and the final recognition of three different critical supersaturation effects :—

Expansion Ratio.	*Supersaturation*	*Ion.*
1·25	4	Negative ion
1·31	6	Positive ion
1·38	8	Water molecules ?

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[1] Wilson—"Proc. Camb.Phil. Soc.," Vol. 9, (1897); "Phil. Trans.," Vol. 192, (1899).

Much other work in connection with atmospheric conditions was being done about this time by Professor J. J. Thomson himself, who had suggested much of the work, by J. S. Townsend, and by H. A. Wilson, with which this paper is not directly concerned. It is with the main line of investigation, from condensation in dusty air to the recognition of the various nuclei that we are mainly interested.

The point of next interest was as to the charge carried by these ions—there was no question of a charge on the nuclei concerned in the eightfold supersaturation, but an investigation of the positive and negative charges on the small ions (four and sixfold supersaturations) was required. The velocity of the cloud formed when $\frac{V_2}{V_1} = 1{\cdot}25$ or $1{\cdot}31$ could be followed when moving in different electric fields, affording a reliable method of calculation of the mean charge on each drop. The work of Prof. J. J. Thomson, published first in the Phil. Mag. Vol. 46 (1898) already referred to and later in the Phil. Mag. Vol. 5 (1903) is the classical determination, and led to the conclusion that the small ion, positive or negative, consisted of a small electrified group of molecules, without any foreign core, the charge being, as expected, $3{\cdot}4 \times 10^{-10}$. Later work has raised considerable discussion as to the actual construction of the ion, and more accurate determinations of the ionic charge have been made.

Mobility.

The work now swings on to the "mobility" of these ions, their mobility being the average velocity they attain when under a potential gradient of one volt per centimetre—and the later qualitative results lie mainly in this field, with the exception of important investigations by Prof. T. H. Laby on condensation in various vapours, referred to again later.

When a field is applied, it is noticed that the ions almost immediately attain a constant velocity, and that velocity is in accordance with the strength of the field.

The fact that the positive and negative small ions have different mobilities was first observed by Zeleny, and recorded in the Phil. Mag. Vol. 46, (1898). If we refer to a later and more complete paper by the same author in Philosophical Transactions, Vol. 195 (1901), we find that his measurements of mobility for the small ions may be tabulated, so far as this paper is concerned, as follows:—

Mobility in dry air.	Positive ion	1·36
	Negative ion	1·87
	Ratio of velocities	1·375
Mobility in wet air.	Positive ion	1·37
	Negative ion	1·51
	Ratio of velocities	1·10

The unit being, of course, one centimetre per second per volt per centimetre.

It is the condition in wet, or saturated, air that is of most interest to us, but the slowing down of the negative ion with increase in relative humidity, whilst the positive ion remains unchanged, has led to the conception of the negative ion as collecting more and more water molecules round it as they become available.

Professor J. A. Pollock, in the Presidential Address before Section A of the Australasian Association for the Advancement of Science, 1909, stated—"The charged molecule will thus collect other molecules round it, but, as the effect of the charge on the outer members of the cluster diminishes as the collection of molecules increases, the growth will cease when the size is such that the attraction of the charge at the surface of the cluster, in grazing impact of ion and molecule, is just sufficient to hold the latter as a permanent member of the ionic system."

All readings quoted are for air, or for air and water vapour; the denser the gas employed, the less the velocity. Zeleny points to the smaller supersaturation required for condensation on the negative ion—"It is interesting to note in this connection the recent results of C. T. R. Wilson, showing that in supersaturated air the water condenses more readily upon the negative ion." The negative ion has a greater affinity for water molecules.

(The ratio of velocities had been given by Zeleny in his earlier papers, but as the hygrometric state of the air was unknown, the results were indeterminate).

This paper does not include within its scope a general discussion of the methods of ionisation, so passes over the extremely interesting work of John S. Townsend, collected in his book "The ionisation of gases by collision," and the lucid summing up of the situation by Prof. Bragg in his Presidential Address before the Australasian Association for the Advancement of Science, 1904, (Section A).

The Langevin Large Ion.

The next ion discovered in the atmosphere was announced by Langevin[1] in his paper "Sur les ions de l' atmosphere." He found, *in ordinary atmosphere*, an ion of mobility $\frac{1}{3000}$.

Papers published by Pollock in 1909 in the Journal and Proceedings of the Royal Society of New South Wales, and in the Phil. Magazine 1915, make a careful investigation of the mobility of the large ion under varying hygrometric conditions, and put forward suggestions as to its nature—a foreign nucleus, electrified, and surrounded by water.

McLelland and Kennedy ("The large ions in the atmosphere," Proceedings of the Royal Irish Academy, Vol. 30, 1912) also find the mobility of the large ion to be in accordance with that stated by Langevin, and give quite a considerable amount of tabulated information as to the number present per c.c. under different weather conditions. We must note in connection with this that—"On a few mornings during which there were 'smoke' fogs, the values were high, but decreased as the atmosphere became clearer." It is also exceedingly interesting to note his further results, that *after* the large ions had been removed by *an electric field* (not by filtration), they reproduced themselves, though not to the same extent as before." Pollock shows that if the air were cleared of dust, either by filtering or by a series of moderate or large supersaturations, the large ion did not recur. This has also been checked under varying conditions by the author.

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[1] Langevin—"Comptes Rendus," Tome 140 (1905).

Obviously this would point to the idea, which is emphasised later, that the nucleus is a "dust" particle, and that the ion is not necessarily electrified to *exist*—it picks up a charge later, and is consequently noticed—but is always available as a condensation nucleus. In other words, the Langevin ion is always considered as an electrified particle, because it has always been its mobility that has been measured.

Where "dust" particles are referred to, the author means matter foreign to the gases or vapour concerned.

The discussion as to the nature of the large ion is by no means finalised—beyond its mobility, and the fact that the number of large ions present varies inversely as the number of small ions, nothing is fixed. As for the structure of the small ion, the outstanding point is only as to whether it consists of a group of molecules, or of one molecule, carrying a single charge. Wellish[1] looks upon it as a single charged molecule, explaining the apparent "loading" in terms of the charge itself.

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[1] Cambridge Philosophical Society, 1908, and Australasian Association for the Advancement of Science, 1909.

Langevin looked upon the large ion as containing at least a million ions of molecular size.

The "Intermediate" Ion.

With reference to the "intermediate" ion of Pollock, published in the Phil. Magazine, Vol. 29, 1915, under the heading "A new type of ion in the air," all work in any way conclusive on various types of ion present in the atmosphere may be considered ended to the present. This ion has a mobility of $\frac{1}{50}$ approximately, depending, like the other ions, on the state of saturation of the air, and disappears if the vapour pressure exceeds a certain value (15 mm. Hg). This ion is supposed by its discoverer to consist of a rigid core, enveloped by a dense atmosphere of water vapour. The possibility of an ion of this type had been pointed out previously by Sutherland.[1]

Ions Produced by Spraying.

There now opens up the discussion of the effects produced when a gas bubbles through a liquid. A considerable amount of work has been done in this field, both as to the electrification effects produced, and as to the possible formation of ions. It is this latter series of investigations which concerns us. The work of earlier investigators had shown electrification effects produced when splashing or bubbling took place, so one is dealing here with the idea of charged "spray," the drops composing the spray being of ionic dimensions.

It will be noticed throughout previous work referred to in this paper that any bubbling or splashing caused complications, the air being filled with minute drops, which cause condensation on the least supersaturation. The idea is that each small drop would act as a nucleus, just as the water molecule acts as a nucleus for the great supersaturations. Associated with this work—that is, the attempt to locate definite new ions in spray—we find the names of McLelland, P. S. Nolan, J. S. Nolan, and Blackwood. J. S. Nolan[1] finds no less than *twelve* distinct groups of ions, of mobilities 0·00038, 0·0010, 0·0043, 0·013, 0·046, 0·12, 0·24, 0·53, 1·09, 1·56, 3·27, and 6·25 cms/sec/volt/cm. These ions carried both positive and negative charges, except the fastest, which was only found negative.

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[1] Phil. Magazine, 1909.

It seems quite possible that the air was not "dust free," and that, although distilled water was employed, it may have abounded in foreign nuclei. He refuses to admit a blending from group to group, which might indicate the continuity in size of the droplets which might be expected.

Later work[2] leads to the same results with undried filtered air bubbled through mercury. It is claimed that these new ions have no nuclei—they are merely a grouping of water molecules. A further paper[3] discloses mobilities of up to 27·0 cms/sec/volt/cm.

Nolan next draws attention to the bubble ion of mobility 0·047, for which he deduces a corrected radius of $3·8 \times 10^{-7}$ cm. approximately. He takes his ion of mobility 0·00038 (corresponding to the mobility of the Langevin ion) to have a radius of $4·16 \times 10^{-6}$ cm.—this is his largest ion—and to the ion at the other end of the group of five he gives a mobility of 0·047, and a radius of $3·8 \times 10^{-7}$ cm. The stable ion, as calculated by Thomson and by Langevin[4] has a radius of 5×10^{-7} cm. So Nolan takes his ion mobility 0·047 as being the stable ion.

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[1] J. S. Nolan, Proc. Roy. Soc., Vol, 90, (1914); Proc. Roy. Irish Acad. Vol. 33, (1916).

[2] Nolan & McLelland, Ibid., 2nd paper.

[3] Nolan, Proc. Roy. Soc., Vol. 94, (1918).

[4] Conduction of Electricity through Gases, and Chaveau, 'Le Radium,' 1912.

There does not appear to be a sufficient reason for taking this group of five ions separately—it would seem just as correct to take his next ion, 0·12 mobility, as fulfilling this "stable ion" condition, if worked out purely on a surface tension—vapour pressure balance. Electrification can make no difference in ions of this size, as will be seen later.

In summing up and putting forward a theory as to the number of water molecules composing these ions, Nolan takes the stand that the small ion in *dry* air is the simple molecule (Wellish) or group of molecules of the gas, whilst in saturated air the small ion is this dry ion with water molecules tacked on, no other impurity being present. This certainly fits in with all experimental evidence, and is in accord with the views of most physicists. He also draws attention to the fact that in dry air the mobility (negative ion) is given as from 1·93 to 1·70 (apparently depending on the care with which drying is carried out) and in "wet" air is 1·5 approximately. This would seem to contradict the possibility of the existence of definite stable ions with mobilities between 1·5 and 1·93—yet Nolan's ions are 1·49, 1·70, 1·94. Is not this middle ion, mobility 1·70, a "paper" ion only, resulting from a mixture of ions with water molecule affinities satisfied to different degrees? Beyond this he proceeds by nine ion steps to the one previously referred to, mobility 27·0.

In the "Physical Review," August 1920, Volume 16, Oswald Blackwood gives the results of his research into this type of spray ion, in an attempt made to repeat the Irish experiments. He was quite unsuccessful, finding a continuous band of spray ions, and no division into groups. He employed a Zeleny tube for mobility determinations, and would certainly seem to have had every opportunity of determining the series of lasting spray ions, if such were produced.

He also produced ions by employing a red hot platinum wire as an ioniser, and found that he got a continuous band effect, the *mean* mobility of the ions present in every case increasing with time since formation, "indicating that the rate of condensation of water vapour is constant and independent of its (the drops) size."

He was working on small time periods only in his more precise work, up to 70 seconds. Figure 1 shows a comparison of mobilities (mean) and age, the data being taken from Blackwood's paper.

If the curve be asymptotical to the line mobility = 0, then the drops will grow to an infinite size. But it is more

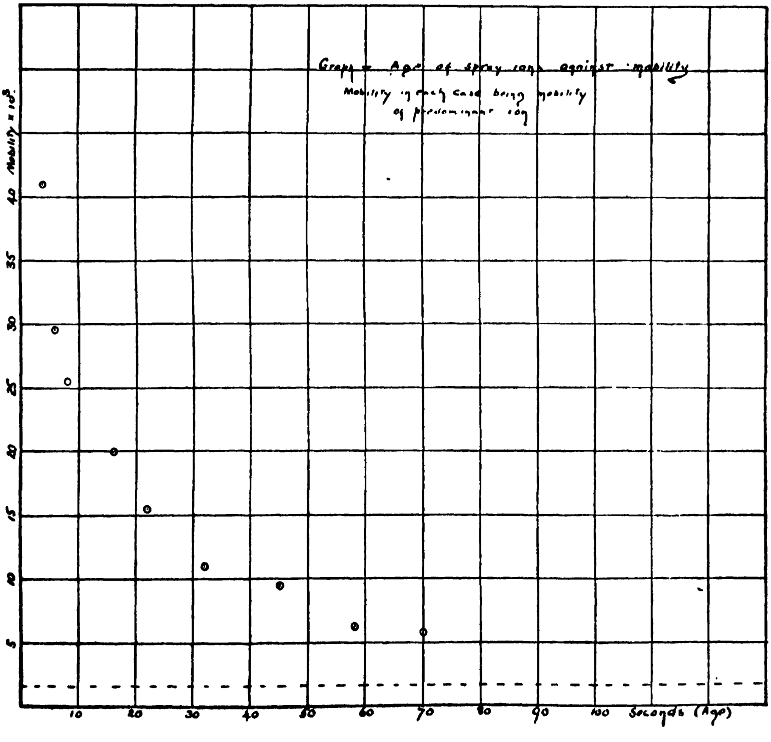


Figure 1.

probable, in view of other work, that the curve is really asymptotic to some other line—I think it will prove to be the line K=0·00033—showing that the drops eventually reach a stable condition.

No matter what the mobility of this stable ion turns out to be, experimental evidence shows that one does exist.

Research is now underway to allow for much greater ageing of these droplets. Blackwood's work, then, may be summed up:—On spraying, ions of many different mobilities are present. These spray ions grow with time, *not necessarily indefinitely*. At any particular moment ions of one size predominate.

He states "The conception which one gains from the above experiments as to the nature of the large ions is consistent with the views published in the papers of Barus, Aitken, Pollock, Lenard, and others. It is not at all inconsistent with the experiments of C. T. R. Wilson, as explained by Thomson. According to our results, the original nucleus of the large ion may be an agglomeration of a few molecules of water or a few particles of dust which have gathered a charge either by the process of formation (spraying of water), or by picking up a charge while passing through the ionised gas surrounding the hot platinum filament. These nuclei, due in part to this charge, may continue to grow by condensation of water vapour or by agglomeration into larger units, at a rate depending on the concentration of water vapour, and on the time interval in which the ions have had a chance to reach equilibrium. The detection of the particle or nucleus as an ion, and possibly to some extent its dimensions, are dependent on its acquiring a charge at some stage of the process. The explanation of these results in no way demands the growth of the large ion through the clustering of water molecules round a single charge."

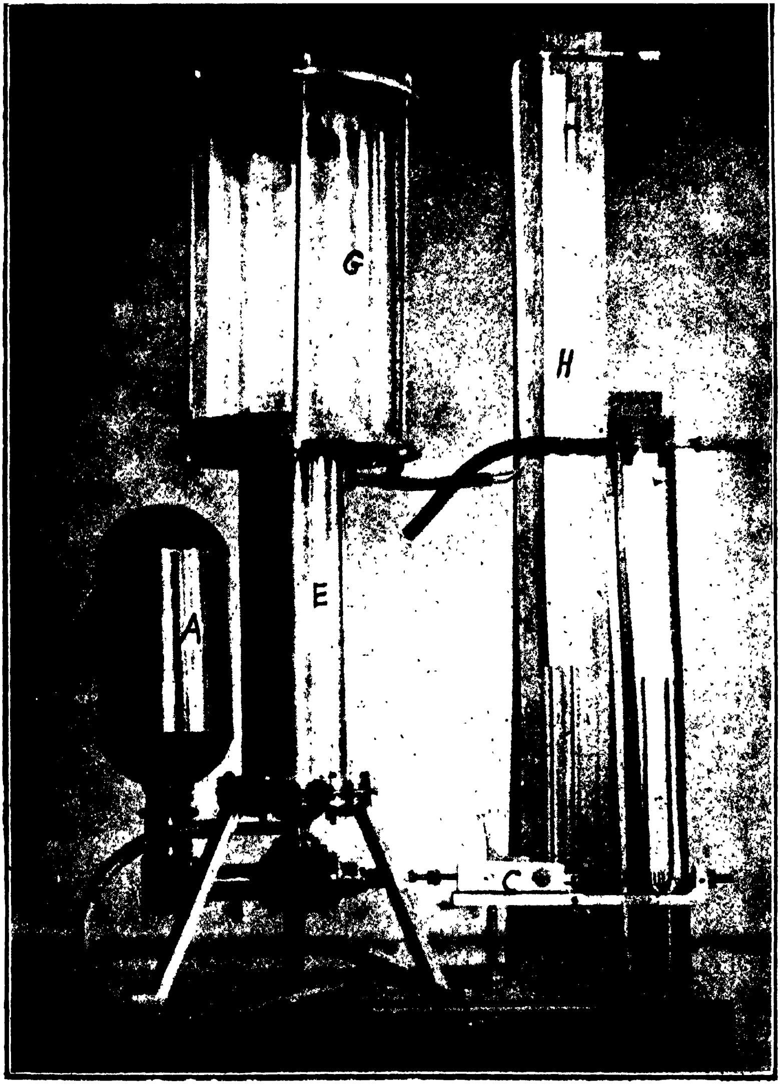
The author, as a result of experiments described later, would go further, and say that a foreign nucleus was essential, and that the charge, whilst necessary as a means of detection if a mobility method be employed, is not required. Whether the large ion would be called an ion if unelectrified is a matter of definition.

In the "Physical Review" of September, 1921, P. J. Nolan returns to the question, and finds not only the spray ions originally discussed, but also some evidence of intermediate groups. He explains Blackwood's negative results —"It is suggested that since ions are constantly changing from group to group, definite peaks can only be expected if the time spent by each ion in the measuring chamber is relatively short. In Blackwood's experiments this time was from 9 to 150 seconds, whereas it was only 0·5 to 13 seconds in the experiments reported here."

It would seem that an ion, given a nucleus, can have any number of water molecules tacked on to it, till some stable form is attained in saturated vapour. That even if the vapour be not saturated, the stable Thomson ion should still form in equilibrium with the vapour. So one must expect to get from spraying a continuous range of mobilities instead of isolated groups, growing to the one stable ion with time.

The point that had now been raised by many observers, that all Aitkens "dust" nuclei were really merely conglomerations of charged water molecules, requiring no foreign core, caused him to make a further set of investigations, which are published in the "Proceedings of the Royal Society of Edinburgh," Vol. 37, Part III, 1917.

He remains convinced that the nuclei are dust, and that in a gas-lit room the air can be cleared by repeated small expansions; but brings forward the fact that smaller ions do exist in the outside air in small numbers, intermediate


G
H
E
A
C

condensations being found on the way up to the fourfold supersaturation.

The first Series of Investigations by the Author.

The first investigation commenced by the author in the Physical Laboratory of the University of Sydney, at the suggestion of the late Professor Pollock, was to examine the nature of the nuclei in ordinary unfiltered laboratory air by means of small supersaturations, to find if any critical supersaturation could be found corresponding to any particular group of ions. Also, to determine the minimum expansion necessary to clear dusty air.

H. Kennedy[1] suggests "That the nuclei measured by Aitken were not dust particles in the form of solid matter in a very fine state of subdivision, but were identical with the large ions and the uncharged nuclei, from which large ions may be formed by ionising the air in which these nuclei occur." This would demand a small critical supersaturation to bring them down. Kennedy finds that the charge on the large ions is variable, but the mobility constant. This would not affect the supersaturation required on a body of this size.

The apparatus employed is of the type used by Wilson, as described in the Phil. Magazine, June 1904. This is shown in Fig. 2 and Plate XI. The vacuum vessel A is connected through a stop cock to a vacuum pump, and is kept closed to the rest of the apparatus by the rubber stopper B, which is held against the vacuum chamber opening by the atmospheric pressure. A trigger and spring release C enable the stopper B to be jerked back suddenly, establishing communication between the vacuum vessel and the under surface of the piston D, which can be previously pushed up to any required height in the cylinder E by blowing through

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[1] "The large ions and condensation nuclei from flames," Proc. Roy. Irish Acad., Vol. 33A, p. 58.

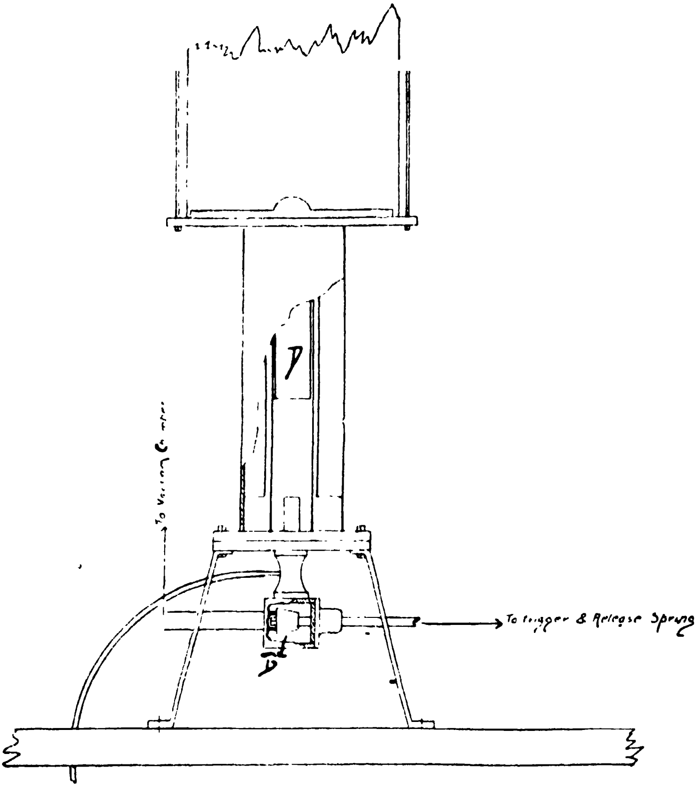

Fig. 2.

the inlet F. This can be closed then by a stop cock. On top of the cylinder and piston is the glass expansion chamber G, sealed in position so as to be quite airtight. This expansion chamber is referred to by Wilson as the "cloud viewing chamber." The pressure in the expansion chamber is read on the manometer gauge H. (Two gauges, water and mercury, are provided.) Full precautions are taken as to sealing all parts of the apparatus to prevent any possibility of communication between the expansion chamber and the outside air, by providing all flanges with rubber separators, the joints being again carefully waxed outside that. The expansion chamber has a rubber pad at top and at bottom, being squeezed between the two by means of columns J. The piston rests on a rubber pad at the end of its stroke—this is essential, as otherwise the shock of falling soon burrs up the edge of the piston, forming a leak to the vacuum chamber, and nullifying the whole experiment. Some difficulty was experienced in finding a rubber sufficiently soft to ensure a perfect seal being established by the piston at the bottom of its stroke, and which would not be cut through by the repeated blows with the sharp edge. Red rubber sheet, $\frac{3}{16}$ inch thick, was found most suitable.

As only small expansions were required, a small piston was employed (a false cylinder lining enabled this to be done) with a large expansion chamber. The chamber had a volume of 8,647 c.c., the piston having a diameter of 2·3 cms.

The principle involved is, of course, an adiabatic volume change by the rapid pulling down of the piston, with the corresponding drop in temperature and consequent supersaturation.

It was readily seen that any splashing from the plunger would upset the experiment, so a splash glass was placed in the expansion chamber over the cylinder to obviate any errors due to this cause. The illumination was from an arc lamp initially, brought to a focus in the centre of the chamber, the light being admitted through a small opening in a dead black screen, and viewed through another opening 20° off the direct line of light. The bright drops could be seen falling or floating against a black ground, and the intensity of illumination varied from the sides of the chamber where the cone of light was at its bases and thus a large "field of view" given, to the centre of the chamber where the field of view was small, but the illumination intense. A water bath was employed between lamp and chamber to absorb heat radiations.

On filling the expansion chamber with air (either sucked in without filtering through a bye-pass on the pressure gauge tube, or merely collected on assembling the apparatus), a very large number of dust particles could generally be seen floating in the cone of light. Immediate expansion on admission of fresh air could, in many cases, be taken up to a pressure change of 20 cms. H_2O without formation of fog—the air obviously took some time to saturate. At first considerable time was allowed for saturation. Later, moist filter paper on the sides of the apparatus where it would not affect the required dark background was employed to expedite saturation. In all cases it was found that considerable time was required to ensure that the air would be saturated.

After standing one hour, the least expansion found pracicable with this apparatus (0·4 cm. H_2O) was sufficient to cause a "coloured" fog.

Standing for twelve hours was generally sufficient to clear the air of all visible particles—but an expansion of 2·0 cms. H_2O even after that period was usually sufficient to cause fog. Standing for two days was sufficient to allow of expansions considerably greater than this being taken without the formation of fog or mist. It is to be observed that up to a limit (noted later) the expansion required to produce fog increases with increase in time of standing.

Several series of experiments were taken both with this apparatus, and employing very large spherical glass flasks (12″ radius) to see if any relationship could be worked out for the time taken to "settle"—or disappear—by these large nuclei, and the condensation required to produce fog or mist, but no law could be determined. It probably depends on many factors such as size of chamber, area of surface exposed for settling, initial state of air, etc.

This would appear to contradict Kennedy's statement that only the large ion has to be considered—unless he goes further, and looks on the large ion as capable of collecting more large ions, so as to form a series of very big ions, larger than any yet recognised in any work. But the pressure changes were found to be the minimum ones to cause the necessary supersaturation for the largest particles yet extant.

We are forced to accept Aitkens original explanation, that these nuclei are actually foreign matter, or "dust particles" in the air, which take different times to settle.

The experiment of clearing the unfiltered air by X Ray ionisation, and the application of an electric field was repeated as a test on the apparatus, and it was found that *all* particles could be readily removed, so that no condensation could be produced up to the limit of pressure variation of the apparatus. For this purpose the top cover of the expansion chamber was constructed of a thin sheet of aluminium, and the chamber contained two insulated plates, distance apart 5·0 cms., and maintained at a potential difference of 480 volts by means of a set of small accumulators. The average time taken to completely clear the air by this method, starting with fresh air, was thirty minutes.

With this apparatus, in very many cases it was noted that if the air were allowed to stand untouched sufficiently long—generally of the order of sixty hours or more—it was clear up to an expansion of 8 cms. (All pressure variations are in water units unless otherwise stated). If allowed to stand for longer periods, of the order of one week, expansions up to the limit of the apparatus as then adjusted (30 cms.) could be taken without any condensation occurring. The occurrence in the vicinity of 8 cms. was always rainlike; if rain occurred then, it was found to persist up to the maximum expansion taken. This is to be expected—

if the nuclei are present, the greater supersaturation will merely mean bigger drops if they exist alone. The number of drops was very variable. In few cases did the air clear on standing so that an expansion greater than 8 cms. was required to bring rain; if it was clear to 8 cms. it was usually found to be clear to the limit of expansion (30 cms.) (In these few cases, an expansion of between 13 and 18 cms. caused rain.)

An *increase* in rain was frequently noted from 13–18 cms. This was most pronounced—though possibly only by contrast—if only a few drops occurred at 8 cms.

As previous observers had definitely stated that the air could be cleared of all nuclei up to an expansion ratio of 1·25, by repeated expansions at 1·02, a large number of expansions at 25 to 35 cms. were taken, but rain was often obtained after the fog had been cleared. It was considered possible that some very small leak, insufficient to appreciably affect the pressure gauge, might be the cause of this. Consequently readings were now taken with the chamber pressure always in excess of the external atmospheric pressure, so that any leakage should be *from* the expansion chamber. It was found that this did not affect the result.

It was now noticed that after this eccentric rain had once fallen, rain could be produced at any lower expansion, down to 8 cms. Below this, condensation was not observed. Immediately above it, rain fell. The effect died away in an hour or less.

This appeared to point to condensations on invisible water nuclei, possibly formed by splashing, with the possibility that with this apparatus the higher condensation point (13 to 18 cms.) was governed solely by the expansion at which the piston descended with sufficient violence to project "splashes," which would find their way unhindered into the upper chamber.

Consequently the bottom of the chamber was now closed by a screen of fine bolting, wetted, and placed about 5 cms. up the chamber.

On the first run after the insertion of the bolting, the air was very dusty, and the chamber was filled with swirling fog without any expansion being made. It was allowed to stand for two days, and an expansion of 2 cms. was still sufficient to cause fog. It was not found practicable to clear it by repeated small expansions of 2 – 3 cms., the air being too heavily laden. Neither was it considered justifiable to adopt the method latterly employed by Aitken,[1] and carry out a number of large expansions slowly, as it was considered that it left the state of the air too indeterminate.

After standing a further twenty-four hours, expansions up to the maximum (34 cms.) were taken without rain being obtained. The run was now repeated, with ionisation by X rays proceeding, and no effect was noted until an expansion of 17 cms. was reached. At this point a large splash was seen to strike the bolting. The expansion of 17 cms. was thereupon repeated, rain being the result, as was expected. The apparatus stood for one hour. A run through to 21 cms. was taken without X rays—no rain. With X rays on, after five minutes, with ionisation still proceeding, expansions of 21 and 22 cms. were taken—no rain resulted. (There was no field employed, the plates having been removed). It was subsequently found that the air could always be cleared by repeated expansions of 20 cms. unless splashing occurred.

Cases of splashing were investigated. Any high expansion immediately after a splash, produced rain. Expansions immediately afterwards of 8 cms., 9 cms., and upwards produced rain, but 7 cms., produced no effect; several minutes elapsed between each reading.

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[1] Proc. Roy. Soc. Edinburgh, Vol. 37, p. 220.

This clearly indicated that after splashing, and after waiting about three minutes for stabilisation, rain will occur at expansions of 8 cms. or greater, even in apparently dust free air. No leakage can have been possible, the pressure in the expansion chamber being above atmospheric pressure.

This was repeated on many occasions, it being found that the conditions given above were always repeated also.

No precise time intervals were measured between splash and subsequent readings, during this period of the research.

It will be noted, also, that water pressure variations are given to the nearest centimetre only—the apparatus was so big for the small expansions taken, and the piston movement for the lower readings so small that, although records were keep throughout to the nearest millimetre, the order of accuracy was not nearly so great as would be indicated by that.

It may be well here to investigate the possible effect of a different pressure range, or a different temperature. The expansion ratio is given by

$$\frac{V_2}{V_1} = \frac{\text{Initial gas pressure}}{\text{Final gas pressure}} = \frac{B - \pi - S_1}{B - \pi - S_2}$$

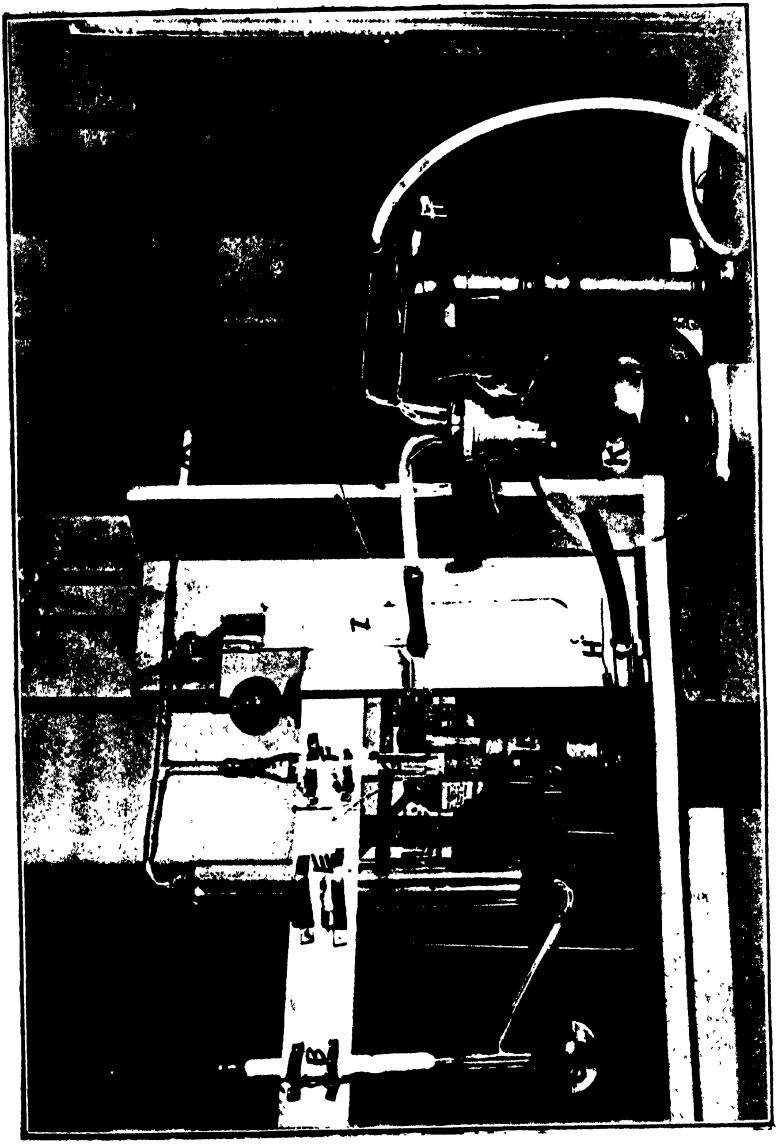
where B is the barometric pressure, π the saturation vapour pressure at the temperature of the experiment, and S_1 and S_2 the initial and final gauge readings.

Taking a typical example of an 8 cms. variation, from 5 cms. above atmospheric pressure to 3 cms. below, where B = 76·6 cms.

$$\frac{V_2}{V_1} = \frac{766 + \frac{50}{13 \cdot 6} - 19 \cdot 66}{766 - \frac{30}{13 \cdot 6} - 19 \cdot 66} = 1 \cdot 0079.$$

Taking atmospheric pressure as 760 m.m., and neglecting the partial pressure due to saturated water vapour, also

Journal Royal Society of N.S.W., Vol. LVII., 1923. *Plate XII.*



taking a total pressure variation of 8 cms. without regard to sign,

$$\frac{V_2}{V_1} = \frac{760}{760 - \frac{80}{13{\cdot}6}} = 1{\cdot}0078$$

so any variation in pressure or temperature should not affect the pressure or volume ratio.

On the other hand, if an error in reading of one centimetre be made in the *pressure change*,

$$\frac{V_2}{V_1} = \frac{760}{760 - \frac{70}{13{\cdot}6}} = 1{\cdot}0069$$

so it would appear illogical to take pressure or temperature variations into account, so long as the pressure change is measured as accurately as possible.

Second Series of Investigations.

Attention having now been directed to an apparently critical condensation point after splashing, as well as to the critical point on standing, a better apparatus was designed to deal with dusty or dust free air for small expansions, where accurate readings could be made, splashing would be cut out and bubbling substituted, and the history of the imprisoned air recorded in detail.

The apparatus is shown in Plate XII. The air is drawn in from the laboratory through the tube A, and through the tube B which can be packed with 20 cms. of cotton wool to filter the air if desired. The flask C, radius 10 cms. holds "distilled" water, which can be tipped or again distilled *in situ* over to the bend D. E is the expansion chamber, a cylinder 38 cms. long and 4·5 cms. in diameter; F is the cylinder, and G the piston, to produce pressure variations in E; I is a water gauge and M an outlet or seal, normally kept filled with 20 cms. cotton-wool as a filter; N is a pinch cock closing this end of the tube; K is the vacuum flask, connected to a water vacuum pump; H and L are the trigger and stopper arrangements by means of which the vacuum chamber is suddenly put into connection with the bottom of the piston. The piston is of glass, being a 1 inch test tube, cut and ground so as to make an airtight contact with the rubber stopper at the bottom of the cylinder. A large number of test tubes were tried, and a selection made of those which fitted the cylinder smoothly, yet with a minimum of play between cylinder walls and piston. The lubricant was the water seal in the piston. Many pistons were broken by shock or cracked, or found to be badly fitting after usage and turning in the cylinder, so a suitable test tube was an article of value.

The apparatus was made chemically clean before being set up, and distilled water was placed in the flask, the filter portions of the apparatus been packed with cotton wool. The air inside was cleared of dust particles by filtration, being drawn from A through 15 cms. of this closely packed cotton wool, and thence through the remainder of the apparatus and out at N. A pressure difference of 20 cms. across the apparatus was found satisfactory. The piston was moved up and down at the same time in its cylinder, to ensure circulation and clearing of air in the cylinder above the piston head.

It was allowed to stand for one hour to ensure saturation, and then tested up to 8 cms. expansion without condensation ensuing.

This portion of the research was an attempt precisely to fix the position of the permanent "splash" nucleus that had required an expansion of about 8 cms. with the other apparatus, and to show that it required a foreign nucleus. For that purpose, not only was it necessary to locate with this apparatus the condensation required on these nuclei, but it was also necessary to bubble through *pure* water, and to show that, allowing a few minutes for ageing, no nuclei larger than the small ion (1·25 ratio) would be present.

A little water was distilled over from the flask to the elbow D. A test now showed that the minimum expansion that was given (2 cms.) caused fog.

The condensation with expansions of so low a value would appear to be due to one of the following causes:—

(a) the accidental admission of dusty air,

(b) particles being given off on heating the flask to distil over the water.

(c) the fact that with the apparatus as arranged, and only a small amount of water in the elbow, bubbling is caused by the expansion, air being drawn through from the flask; since condensation is possible on small drops of water, which have not had time to settle or to evaporate before supersaturation is effected.

(a) was guarded against, and does not seem probable. The explanation might lie in (b), but undoubtedly lies in (c). Whenever an expansion is taken immediately after bubbling condensation ensues on minimum supersaturation.

To ensure pure water in the elbow, it was decided to try repeated distillation without ebullition according to the method of W. H. Martin.[1] Starting with a chemically clean apparatus, "distilled" water in the flask, and with clean air (tested up to 20 cms.) the flask temperature was maintained at 40°C. electrically, the elbow D being at 22°C., care being taken to maintain all possible condensation points before the elbow at the higher temperature. No water distilled over. Attempts were also made by maintaining the flask at 23° C., and later at 45° C., whilst the elbow was in an ice bath. This was equally unsuccessful, the total effect of twenty-four hours attempted distillation being one large drop, and a heavy dew on the inside of the tube.

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[1] Journal of Physical Chemistry, Vol. 24, No. 6.

Repeated attempts were made whilst this was in progress to see if the temperature variations were affecting the air —no condensations were observed on expansions up to 20 cms.

It was now decided that the vacuum chamber and trigger release method was unnecessarily cumbersome for such small expansions and piston movements, and it was found that the piston could be sucked down with great rapidity by mouth, at the tube S. This method was employed in future (except for reversion as a check) and saved much worry.

The distilling trouble was later overcome, but it was decided to postpone temporarily that portion of the work, and to proceed directly with the next portion outlined, to find what condensation nuclei were formed by bubbling through ordinary water.

The method employed was to obtain clean air, and to test it up to 20 cms. This expansion produced no condensation effects even if the air had stood overnight to ensure initial saturation. (We also note the fact that, therefore, no ions "grew" in dust free air). Then water was poured over gently from the flask until the elbow was *filled.* A fresh set of expansions up to 20 cms. produced no effect. (Movement of the water in the elbow occurred, but, being filled, no bubbles passed). Filtered air was now drawn through, and blebbed past the water in the elbow. Within periods varying from 30 seconds to 17 hours afterwards, expansions were taken to find any critical point.

Naturally particular attention was paid to the expansions in the vicinity of 8 cms.—nothing was noticed here. On taking larger expansions, it was found in a large number of different and distinct runs that rain occurred at 12 – 13 – 14 cms. The expansion at 8 cms. was not reached under two minutes after bubbling, as the run always started with the minimum expansion, and worked up by steps.

These condensations were quite decided—tests were made to ensure against incomplete saturation, or for the effect of the small amount of air bubbled through on saturation. In every case it was a distinct rain—never very many drops—thin and difficult to observe on 12 cms. when it was noticed there, but larger drops on 13 and 14 cms. when it appeared there. In no case, provided three minutes had elapsed after bubbling, was condensation noticed before 12 cms.

To endeavour to reconcile this effect with the condensation on 8 cms., found for splashing or as a critical point in standing air with the earlier apparatus, tap water was placed in the flask instead of originally distilled water. Filtered air was drawn through as usual, and the apparatus left to stand overnight.

On testing in the morning for pure air expansions up to 11 cms. gave no effect, but rain occurred on the next expansion taken, 13 cms., although no bubbling had taken place. Evidently the air had not been completely cleared of nuclei admitted during washing and repacking of the apparatus—but the appearance of rain under these conditions with this apparatus at 13 cms. is worth noting.

Fresh air was drawn through for 30 minutes, care being taken to sweep out the cylinder. On being examined 90 minutes later it was found to be clear to 17 cms. (the greatest expansion tested). After standing overnight, it was found clear of nuclei on the following morning. The water was then gently poured over into the elbow. The air was again tested to 17 cms. and found to be clear. Ten bubbles were passed, (by drawing filtered air through the water in the elbow). After one minute a run was started. Nothing was noticed till 13 cms., when rain occurred. (This was three minutes after bubbling).

The air was then cleared (up to 30 cms. the limit of test) by repeated expansions of 17 cms.

With this apparatus, conditions of chemical cleanliness could be observed which were not possible with the earlier one. To test out the apparent discrepancy between the 8 cms. and 13 cms. critical condensations, the new apparatus was allowed to become dirty by permitting dust to settle on the sides of the expansion chamber. An attempt to clear the air by small expansions was unsuccessful, as after standing overnight a mist was produced on 4 cms. expansion (the lowest taken). A number of expansions of 19 cms. were taken to clear the air, and did so as far as the larger nuclei (below 6 cms.) were concerned, Repeated expansions of 9 cms. failed to clear. Specks were seen both rising and falling for some time after expansions, evidently droplets evaporating.

Working with "dirty" apparatus and dusty air is very unsatisfactory, although an explanation of the 8—13 cms. range might be concealed here. The only other explanation apparent would be that there is some apparatus constant. It was thought that possibly sucking the piston down by mouth did not give a true adiabatic effect—this was checked by a run employing the vacuum flask and trigger release again, and found to give the same results.

Possibly the critical expansion required might be involved with the distance of the cylinder from the expansion chamber, and the diameter of the connecting tubes. This has not so far been checked.

Occasional "freak" drops were noticed during runs. In one case the air was cleared by filtration, and after standing overnight was found to be clear, except for one drop which fell through the cone of light on a 15 cms. expansion, and one which fell at 17 cms. These were not repeated on checking. The usual check run was taken, and after passing 25 bubbles was found to give rain, after stabilising, at 13 cms. This was quite an exhaustive run; rain came at 13 cms. and not below.

Another possible source of error lies in the movement of water in the manometer tube. This was a fine bore glass tube, but it must be remembered that the actual volume change is small for a small expansion, so a small error due to surge of water in the manometer tube would be introduced. This condition would apply to both apparatus—but the working volume in the earlier type was much greater.

Experiments were made bubbling unfiltered air through the water in the elbow. Results were very mixed. In every case there was an increased effect at 13 - 14 cms. amounting to a rain, but from 7 cms. up drops kept falling, and on several occasions there were distinct indications of a critical point below the 13 cms. one. But runs were so discordant that no statement can be made.

The point of outstanding interest now was the question of the nuclei required for the 13 cms. condensation. The author was still impressed with the idea that a foreign nucleus was essential, as nothing of this nature "grew" in filtered air; these nuclei would surely be present, in the small number required to produce rain, in water distilled in laboratory stills and condensors.

A further attempt was therefore made to distil water over actually in the apparatus, without ebullition. By reducing the internal pressure to 4 cms. Hg and maintaining the elbow in an ice bath, water came over from the flask and condensed in the elbow quite readily. The flask itself was heated electrically by a coil of high resistance wire, the average water temperature being 35° C. A second coil maintained the cotton wool filter at from 70° - 100° C., to prevent condensation here. Precautions had to be taken to prevent the admission of air past the piston, or the sucking of water out from under the piston, thus breaking the seal. The manometer gauge had also to be closed off.

The air was first rendered dust free by filtering, and checked. Water was distilled over to the elbow, washed round, and drained back into the flask. This distillation and washing was repeated three times. In the first experiments, it was found that condensation occurred on expansion of 12 cms., even without intentional bubbling—this is supposedly due to air given off by the water in the flask when the pressure was reduced to 4 cms. Hg. Little bubbles had been noticed at this time on the sides of the flask.

Great difficulty was experienced in admitting filtered air after distillation, to avoid bubbling on the one hand, or the forcing of the distilled water back into the flask on the other. Filtered air must be admitted to both sides at once, slowly to ensure effective filtration, and at the same rate. This was effected by means of soft glass tubes, drawn out to fine capillary tubes of increasing bore, which were attached to the laboratory side of each filter. The movement of the water was watched, and little bits broken off each tube as required to balance the rate of admission.

Throughout the processes of exhaustion, of distillation, and of readmitting air, the piston was held down on its rubber stopper by maintaining a partial vacuum $<$ 3 cms. Hg under it.

Runs were carried out as follows:—

(A) Air was drawn through the filter. Stood for 30 minutes. Tested up to 30 cms.; no rain.

(B) Pressure lowered to 3·5 cms. Hg, and maintained at that for one hour, still connected to the pump.

(C) Cotton wool filter raised to 100° C. by coil, and maintained at that temperature.

(D) Flask heated by coil to about 35° C.

(E) Elbow placed in ice bath.

(F) Sufficient water distilled over in one hour to rinse elbow. Poured back into flask.

(G) Step F repeated again twice.

(H) Water distilled over to elbow for two hours, without ebullition.

(I) Air readmitted through filters.

In each case, the first run after fresh water had been put in the flask, gave rain on 12 – 13 cms. without any bubbling. This would point to the correctness of the theory that gases are given off from the laboratory distilled water, having a bubbling effect.

Repeating with great care the above programme, and including prolonged initial boiling of water in the flask, standing to cool over night after the final distillation, gave air free from nuclei.

Bubbling now past the water in the elbow gave rain on 13 cms.

It would not be practicable to say whether the number of drops after bubbling through this allegedly pure water was less than after bubbling through tap water. In each case the number was small, giving only a scattered shower through the cone of light.

If this were taken as a positive result, it would tend to show that foreign matter does not compose the nucleus of those large ions, and that water molecules sufficed, as presumed by Nolan. But in view of the other evidence, the author is still convinced that it is a negative result—that it is not possible to have the water "pure" when we are dealing with a few nuclei which are so extraordinarily minute. Possibly the glass in the elbow itself, although carefully washed, gives off sufficient centres of condensation to ensure the 13 cms. rain after bubbling through the water in contact with it.

Further attempts are to be made, not only with water vapour, but with other chemicals. Interlocking evidence should be available from reference to the paper by Prof. T. H. Laby in "Philosophical Transactions," A, Vol. 208, giving the corresponding small ion condensation points for certain vapours, and the paper previously referred to, by Wellish "On the mobilities of the ions produced by Rontgen rays in gases and vapours."

Inspection of Experimental Results.

The results of these experiments, then, so far are:—

(1) Filtered air which is bubbled through water has, after ageing, a critical condensation point corresponding to the supersaturation associated with a pressure change of 12–14 cms. H_2O.

(2) Experiments to show that this is due to nuclei taken up by the water, by employing water carefully distilled, have failed. This is looked upon at present as being a negative result.

(3) There are indications of a critical point corresponding to a pressure change of 8 cms. water, if unfiltered air be employed for bubbling, or if unfiltered air is allowed to clear itself by standing. (The point of "apparatus constant" must be considered here).

(4) "Erratics" are met with—occasional drops coming down from otherwise clean air on expansions greater than 13 cms. water, which do not repeat themselves on repetition of the expansion.

(5) If expansions be made immediately after bubbling, the minimum supersaturation which it is possible to make with the apparatus ensures condensation on some nuclei.

(6) There does not appear to be any simple law connecting time of settling and minimum expansion required to produce condensation in dusty air. The apparatus as at present designed does not permit a careful investigation of the supersaturation required at such low pressure charges. This will be further investigated.

* * * *

Taking a mean critical expansion of 13 cms. H_2O, and noting that the order of accuracy is not affected by minor temperature or pressure changes, the type of nucleus required may be determined.

A typical series gives the following conditions:—

Temperature 25° C. Initial pressure 760 m.m.

For 13 cms. H_2O expansion.

$$\frac{V_1}{V_2} = \frac{76 \times 13{\cdot}6 - 13}{76 \times 13{\cdot}6}$$

The refinements as to weight of piston etc. employed by Wilson are neglected here, as not affecting the result within the order of accuracy of the experiment.

$$\text{Now } \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \frac{\theta_2}{\theta_1}$$

where V_1 and V_2 are the initial and final volumes, θ_1 and θ_2 initial and final absolute temperatures, and γ the ratio of specific heats.

$$\text{So } \left(\frac{1021}{1034}\right)^{0{\cdot}41} = \frac{\theta_2}{298}$$

$$\therefore\ \theta_2 = 296^\circ\ {\cdot}5 \text{ absolute}$$
$$= 23^\circ\ {\cdot}5\ \text{C.}$$

Temperature drop = 1° ·5 C.

The supersaturation corresponding to this drop in temperature may be determined from the equation given by Wilson Phil. Trans. A. Vol. 189).

$$S = \frac{\pi_1}{\pi_2} \times \frac{\theta_2}{\theta_1} \times \frac{V_1}{V_2}$$

Where S is the supersaturation, π_1 and π_2 the pressure of saturated water vapour over a flat surface at the temperature θ_1 and θ_2 respectively.

$$\text{Here } S = \frac{23{\cdot}55}{21{\cdot}52} \times \frac{296{\cdot}5}{298{\cdot}0} \times \frac{1021}{1034}$$
$$= 1{\cdot}075$$

and change in vapour pressure equals $23{\cdot}55 - 21{\cdot}52 = 2{\cdot}03$ mm. Hg. To determine the radius of the nucleus which will be able to grow when the supersaturation corresponds to a pressure change of 13 cms. H_2O, we may employ the equation:—

$$r = \frac{2T}{R\,\theta\,S \log_e \frac{p}{P}}$$

given by Wilson[1] when r is the radius of the nucleus of condensation, T is the surface tension, S the density of the nucleus, R the gas constant, and θ the absolute temperature. $R\theta$ for water vapour at 25° C. $= 1{\cdot}4 \times 10^9$ c.g.s. units, $T = 72$ dynes /cm., S (if water nucleus) = 1.

$$r = \frac{144}{1{\cdot}4 \times 10^9 \log_e \frac{23{\cdot}55}{21{\cdot}52}}$$
$$= 1{\cdot}24 \times 10^{-6} \text{ cm.}$$

This is on a basis of the density of the nucleus being 1.

* * * *

It may be shown from the full equation employed by Sir J. J. Thomson (Conduction of electricity through gases, p. 180).

$$R\,\theta \log_e \frac{p}{P} = \left(\frac{2T}{r} - \frac{e^2}{8\pi K r^4}\right)\frac{1}{S}$$

where e is the charge on the nucleus, K the specific inductive capacity of the surrounding medium, the other terms being as before, that taking $K = 1$, and $e = 4{\cdot}7 \times 10^{-10}$ (single charge) the neglect of the effect of electrification of this size nucleus is unimportant.

That was to be expected, as experimental evidence showed that they were not all electrified, as they still persisted even if in a strong field, provided ionisation was not proceeding by some artificial method; also, there was no difference in critical condensation point which would tend to show a difference in behaviour in this regard between electrified and unelectrified particles.

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[1] Phil. Trans., Vol. 189, p. 305.

Pollock[1] points out "It is not quite clear how the electrical charge of the ions is related to their diameter. The charge is, however, not necessary for equilibrium, and it is not unlikely that the conclusions as to the nature of the ions, only rendered possible by the happy chance of their electrification, may apply with perhaps little modification to many of the far more numerous class of unelectrified nuclei which exist in ordinary air."

Pollock worked out from a kinetic consideration (same paper) an approximate value for the radius of the ion of mobility $\frac{1}{3400}$ in saturated air (the Langevin ion) as 4×10^{-7}. That is one third of the radius of the nucleus under consideration here.

Two points may be noted—firstly, that the density of the ion has been taken as 1, and secondly that a value of 72 dynes/cm. has been taken for the surface tension at 25° C.

The equation is $$r = \frac{2T}{R\theta S \log_e \frac{p}{P}}$$

For r to equal 4×10^{-7}, S must equal 3. There is no reason why this nucleus should not have a density of 3.

How then can we view the large ion? Either as a small core of dense foreign matter, with a large number of water molecules tacked on to it, or as a larger core of less dense matter, with a few water molecules tacked on to it.

Sir J. J. Thomson in the Physical Society Proceedings, Part I, Vol. 27 (1914), deduces a kinetic theory equation which enables the large ion to be calculated as $4{\cdot}16 \times 10^{-6}$, when Mililkan makes it $4·08 \times 10^{-6}$.[1] An approximate value from these two sources then may be taken as 5×10^{-6} cm. Then the 13 cms. H_2O nucleus is only one-third of this size, if composed of water, and if $T = 72$ dynes/cm.

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[1] Phil. Mag., Vol. 29, p. 524.

Thomson[2] dealing with the effect of variation of surface tension with thickness of film involved, explains the condensation on water molecules by means of an eightfold supersaturation on this basis. But here we are dealing with a nucleus ten times the radius of a water molecule (if $r = 4 \times 10^{-7}$) or thirty times the radius of a water molecule (if $r = 1·2 \times 10^{-6}$ cm.).

It is unfortunate that information in connection with thin films of this order (a small fraction of a wave length), is not definite.

If we examine the possibility of 8 cms. being a critical point, we find—

$$\frac{V_1}{V_2} = \frac{76 \times 13·6 - 8}{76 \times 13·6} = \frac{1026}{1034}$$

and $\left(\frac{1026}{1034}\right)^{\gamma^{-1}} = \frac{\theta_2}{298}$

$\therefore\ \theta = 297^\circ·0$ C.

Representing a drop of 1° C.

The radius of the nucleus concerned is—

$$r = \frac{2\,T}{R\,\theta\,S \log_e \frac{23·55}{22·18}} = 1·71 \times 10^{-6} \text{ cm.}$$

So that a relatively big difference in pressure change does not show such a big difference in theoretical nucleus radius. The "erratics" would show radii of the order 1×10^{-6} cms.

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[1] J. S. Nolan, Proc. Roy. Soc., A, Vol. 94, p. 124.

[2] Conduction of Electricity through Gases, p. 184.

The point has been raised that after an eightfold supersaturation, causing fog in dust free air, any expansion afterwards would produce rain, until the air was again cleared.

A series of experiments on this showed that there was no definite condensation point for these nuclei—working with the Wilson apparatus, and taking big expansions, it was evident that these nuclei grew smaller and smaller, until the full expansion ratio 1·25 was again required to produce even a few drops (*i.e.*, until the size of the small ions was reached). This would show that the water droplet—for clearly no foreign nucleus could here be present—was not stable, but disappeared with time, gradually evaporating. The Langevin large ion, on the other hand, is persistent, and does not occur in dust free air. Once the air was cleared, and no bubbling or splashing occurred, there was no sign of any nucleus from the minimum tried up to the expansion required for the small ion.

It is possible that the nucleus on which condensation ensues with the 13 cms. (radius $1{\cdot}24 \times 10^{-6}$ cm. if water, or correspondingly less if density is greater than 1) is not the large ion. But it is of the same order, is very stable, and there is no sign of any other supersaturation from that corresponding to 1 cm. H_2O up to fourfold supersaturation.

The author then considers that the nucleus, radius of the order $1{\cdot}24 \times 10^{-6}$ cm., is the stable ion, mobility $\frac{1}{3400}$ in air saturated with water vapour, corresponding to the Langevin large ion. That this ion has a foreign nucleus, and consists of an Aitken "dust" particle surrounded by water molecules. The density of the whole nucleus might not be much greater than 1. That the short lived ions of Nolan are large ions, which have not yet picked up their full complement of water molecules, though it has not yet been explained why this should not make a continuous range of mobilities.

Work is now being undertaken to determine the mobility of the stable ion produced by bubbling or splashing. Air stored under pressure over water in a reservoir is forced through cotton wool filters, then bubbled through water, passed through ageing tubes, thence through a zeleny mobility tube, through the expansion apparatus and through a meter. This will also be checked with other liquids than water.

I have to record my debt to the late Professor Pollock, for the interest he took in the work up to the time of his death, and for the encouragement and advice he offered during the periods when various forms of apparatus and various tests led to purely negative results.

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THE GERMICIDAL VALUES OF AUSTRALIAN ESSENTIAL OILS (EXCLUSIVE OF EUCALYPTS) AND THEIR PURE CONSTITUENTS, TOGETHER WITH THOSE FOR SOME ESSENTIAL OIL ISOLATES AND SYNTHETICS.

PART I.

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[*Read before the Royal Society of N. S. Wales, September 5, 1923.*]

THIS paper is a continuation of the one dealing with the germicidal values of the principal commercial Eucalyptus oils and their pure constituents read before the Society on 6th June, 1923.[1] As stated therein, we proposed treating of other Australian essential oils and their constituents, as well as some essential oil isolates and synthetics, and the tables given herein form a Part I contribution thereto. Discussion of the results obtained is reserved for a later communication. It is hoped that as an outcome of this work some of the substances examined may be utilised in the preservation of antisera and other similar products which at present are prevented from bacterial decomposition by the addition of carbolic acid and the mixed cresols. The addition of these latter substances to antisera gradually destroys their active principles resulting in a considerable loss to the manufacturer, and also increasing the dose that has to be administered into the patient.

Experimental.

The Rideal-Walker tests were carried out as described in previous papers,[2] standard suspensions of 1% of the oils and the constituents being prepared in 7½% rosin soap solution, with the exception of xylene musk which was best prepared in acetone solution. The co-efficient of this solvent was found to be 0·028. Although the co-efficient of thymol had been previously accurately determined, its re-determination was deemed necessary for comparative purposes, as well as with a view to ascertaining if the phenol now being manufactured in Sydney from piperitone possesses the same germicidal value as the natural isolate. Those substances which were not actually separated from Australian essential oils were carefully purified from preparations ex Museum stock. A specimen of cymene of Continental origin was tested for comparison against a preparation from *Eucalyptus lactea* (see paper read 6th June, 1923) but identical results were obtained.

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[1] This Journal, Vol. LVII, 80—89, (1923). [2] Vol. LVI, 219 - 226, (1922).

Table "A."—*Crude Essential Oils.*

Crude Oil.	Constants. (R I.=Refractive Index)	C.A. Co-efficients.	Principal Active Constituents.
Backhousia citriodora	Sp. gr. $\frac{15}{15}$°C. 0·8920 Opt. rot. + 0·25° R.I. 20°C. 1·4852 Citral 95%	16	Citral
*Doryphora sassafras**	Sp. gr. $\frac{15}{15}$°C. 1·0268 Opt. rot. +18·6° R I. 20°C. 1·5189 Safrol 60 - 65%	13	Safrol Camphor Eugenol
Homoranthus flavescens (Terpene oil)	Sp. gr. $\frac{15}{15}$°C. 0·8206 Opt. rot. +1·5° R.I. 20°C. 1·4873	2	Ocimene
Homoranthus virgatus (Terpene oil)	Sp. gr. $\frac{15}{15}$°C. 0·8809 Opt. rot. +18·5° R.I. 20°C. 1·4801	1	d-*a*-pinene
Leptospermum citratum	Sp. gr. $\frac{15}{15}$°C. 0·8833 Opt. rot. +3·95° R.I. 20°C. 1·4701 Aldehydes 95%	15	Citral and Citronellal
Leptospermum flavescens	Sp. gr. $\frac{15}{15}$°C. 0·9402 Opt. rot. +12·2° R.I. 20°C. 1·4906	4	Citral

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* It was found that the suspension of this oil gradually increased with age, varying from 9 to 13.

Table "B."—*Pure constituents of Essential Oils.*

Constituent	Nature.	Source.	Constants. (R.I.=Refractive Index.)	Coefficient.
Cymene	hydrocarbon	Museum stock	B.Pt 173½ - 174½°C. at 771 mm. Sp. gr. $\frac{15}{15}$°C. 0·8611 inactive R.I. 20°C. 1·4883	8
Ocimene	olefinic terpene	*Homoranthus flavescens*	B.Pt. 75 – 76°C. at 20° mm. Sp. gr. $\frac{15}{15}$°C. 0·8034 inactive R.I. 20°C. 1·4859	3
Thymol	phenol	Merck's ex Ajowan	M.Pt 51·5° C.	25
Thymol	phenol	oxidation of piperitone	M.Pt 51·5° C.	25
Menthone	ketone	reduction of piperitone	B.Pt 207 – 208°C. Sp. gr. $\frac{15}{15}$°C. 0·902 Opt. rot. – 0·15° R.I. 20°C. 1·4529	10
Menthol	alcohol	Museum stock	M.Pt 43 – 44°C. $[\alpha]_D$ 20°C. – 50°	19
Borneol	alcohol	do.	M.Pt 204°C. (in soap solution only)	10
			$[\alpha]_D$ 20°C. – 35·26° (do. + ethyl alcohol to increase dispersion)	15
Citronellol	alcohol	reduction of citronellal ex *E. citriodora*	B.Pt 117 - 118°C. at 17 mm. Sp. gr. $\frac{15}{15}$°C. 0·8615 Opt. rot. + 0·16° R.I. 20°C. 1·4560	14
Camphor	ketone	*Doryphora sassafras*	M.Pt 179°C, $[\alpha]_D$ 20°C. + 42°	6
Safrol	phenol ether	do.	B.Pt 109 - 110° C. at 10 mm. M.Pt + 11°C. Sp. gr. $\frac{15}{15}$°C. 1·103 R.I. 20°C. 1·5375	11
Iso-safrol	do.	Museum stock	B. Pt 122 – 123°C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 1·260 R.I. 20°C. 1·5740	12

Table "B."—*continued.*

Constituent	Nature	Source	Constants (R.I.=Refractive Index.)	Coefficient
Eugenol	phenol	*Doryphora sassafras*	B. Pt 125 – 126°C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 1·0705 R.I. 20°C. 1·5390	15
Leptospermol	phenol	*Leptospermum flavescens*	B. Pt 145 – 146° C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 1·073 inactive R.I. 20° C. 1·5000	under 1
Thujone, *a*	ketone	*Boronia thujona*	B. Pt 79 – 80°C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 0·9157 Opt. rot. – 66·22° R.I. 20°C. 1·4506	12
Elemicin	phenol ether	*Backhousia myrtifolia*	B. Pt 144 – 147°C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 1·0665 inactive R.I. 20° C. 1·5285	just under 1
Croweacin	do.	*Eriostemon Croweii*	B. Pt 130 – 132° C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 1·133 inactive R.I. 20°C. 1·5330	2
Terpin hydrate	...	prepared from pinene	M. Pt 117° C.	1
Heliotropine	aldehyde	Museum stock	M. Pt 37° C.	3
Ionone, *a*	ketone	do.	B. Pt 128 – 130° C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 0·9382 Op. rot. inactive R. I. 20°C. 1·4980	1·75
Musk, Xylene	...	do.	M. Pt 110 – 111°C.	4*
Methyl salicylate	ester	do.	B. Pt 97 – 98°C. at 10 mm. Sp. gr. $\frac{15}{15}$°C. 1·1877 R. I. 20°C. 1·5350	5·5*

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* *Xylene Musk.*—The value given is probably on the low side, as a considerable amount of the material precipitated on dilution. *Methyl salicylate*—This preparation coagulated on standing for about a month when the co-efficient fell to nil. It may be mentioned that so far as our experience goes it appears that the co-efficient of esters depends upon the acid radical, and is independent of the alcohol, irrespective of whether the latter possesses a high or low value.

Table "B"—*continued.*

Constituent.	Nature.	Source.	Constants. (R.I.=Refractive Index)	Coefficient.
Acetophenone	ketone	Museum stock	M. Pt 20·5° B. Pt 199 – 200° C. at 771 mm.(u.c.) Sp. gr.$\frac{15}{15}$°C. 1·0333 R. I. 20° C. 1·5335	4
Isoamyl alcohol	alcohol	do.	B. Pt. 230° C. at 752 mm. Sp. gr.$\frac{15}{15}$°C. 0·8217 Opt. rot. – 1° R. I. 20°C. 1·4070	2
Isobutyl alcohol	do.	do.	B. Pt 105 – 107°C. at 751 mm. Sp. gr. 0·8072 R.I. 20°C. 1·3952	2

PRELIMINARY NOTE ON THE ELECTROLYTIC REDUCTION OF PIPERITONE.

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and

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[*Read before the Royal Society of N.S. Wales, September 5, 1923.*]

In a paper read before this Society in June, 1920, entitled "On the Manufacture of Thymol, Menthone and Menthol from Eucalyptus Oils," by H. G. Smith, F.C.S., and A. R. Penfold, F.C.S., Vol. LIV, pages 40 – 47, it was shown that by the hydrogenation of piperitone in the presence of nickel at 175 – 180° C. menthone was readily produced in almost quantitative yield. Since then a series of experiments on the electrolytic reduction of piperitone has been commenced in this laboratory, but considerable time must yet necessarily elapse before the work is completed, and the results made available for publication. On account, however, of recent enquiries for an alternative method for the preparation of menthone from piperitone other than that mentioned above, it was deemed advisable to make known one of the results so far obtained in order to facilitate its commercial development.

The conditions described under "experimental" were found to readily yield isomenthone in practically quantitative yield, entirely free from pinacone or resinous products. The process is simple, clean, and efficient, and should readily lend itself to commercial application, especially as the reaction proceeds smoothly at a temperature of 20 – 30° C.

Experimental.

A small platinum spiral was employed as an anode, which was placed in 10% sulphuric acid solution contained in a porous cell. The cathode consisted of activated nickel foil, cylindrical in shape, 0·1 mm. thick and surface area two square decimetres, which surrounded the porous pot, the whole being placed in a suitable glass cell.

The nickel was activated by passing it through hot nitric acid whereby its surface was etched, and finely divided nickel was slowly deposited upon same during the process of reduction by adding 1·5 to 2 grams of a nickel salt, either the nitrate or sulphate, to the cathode liquid. The cathode liquid was made up, as follows:—

100 c.c. piperitone (Sp. gr. $\frac{15}{15}$° C. 0·9374, optical rotation −11·1° refractive index 20° C. 1·4832.)
350 c.c. special methylated spirit (95%).
50 c.c. 10% sulphuric acid
1·5 to 2 grams solid nickel salt.

The complete cell was kept cool by immersion in a bath of running water, and a current density of 3·5 to 4 amperes was employed. An E.M.F. of 8 – 12 volts was maintained, the reaction being completed in 12 – 13 hours. If the amperage showed signs of falling off during the process of reduction, small quantities of 10% sulphuric acid, usually about 10 c.c., were added at intervals, until the total volume of acid added to the cathode compartment totalled about 70 c.c. After completion of reaction, the cathode liquid was poured into water, and the separated ketone purified by steam distillation, if desired. It distilled between 207 – 213° C. at 760 mm., over 90% boiling at 207 – 209° C. The chemical and physical constants were as follows:—

Specific gravity $\frac{15}{15}$° C.	0·904
Optical rotation	+ 5·2°
Refractive index 20° C.	1·4560

The oxime melted at 80° C., whilst the semicarbazone appeared to be a mixture of two isomers. On treatment with boiling ethyl alcohol a very sparingly soluble form was obtained which melted at 218 – 220° C., together with a more soluble one melting at 214 – 215° C. This lower melting point was probably due to the former being contaminated with a more soluble isomer. The product of reduction is, therefore, apparently almost entirely isomenthone.

A sample of commercial piperitone (90% ketone) of optical rotation – 49·45° yielded under the same conditions of reduction an isomenthone of optical activity + 43°.

The semicarbazone was found to consist largely of a form very soluble in ethyl alcohol melting at 113° C., together with a small quantity of the sparingly soluble isomer melting at 218 - 220° C. Further data will be made available in our next paper.

THE SECRETORY EPIDERMAL CELLS OF CERTAIN EUCALYPTS AND ANGOPHORAS.

By M. B. Welch, B.Sc., A.I.C.,
Technological Museum.

[With Plates XIII, XIV, and Text Figure.]

[*Read before the Royal Society of N.S. Wales, October 3, 1923.*]

The presence of a transparent elastic substance on the young shoots of certain species of the Corymbosæ group of Eucalypts and also in certain of the Angophoras is well-known, but no description of the responsible dermal glands has apparently been given. Glandular surfaces are not, however, confined to these particular Eucalypts, but also give rise to the glaucous waxy bloom on such species as *E. pulverulenta*, *E. globulus*, etc., and as De Bary(1) points out, this form of secretion is most common from such glandular areas. H. G. Smith(2) has investigated the occurrence of the elastic substance in *Eucalyptus corymbosa*, *Angophora lanceolata*, and *A. intermedia*, and from a chemical examination has found that it resembles in appearance and ordinary general character the caoutchouc or India rubber of commerce. As shown by Smith, the secretion is confined to the very young leaves and shoots, gradually becoming less prominent as the leaf bud opens out and the leaves become larger, the abaxial foliar surface retaining the secretion for the longer period. In young leaves the rubber forms an entire covering both above and below the leaf, both lamina and petiole, and also extends along the upper portion of the stem. Maiden(3) states under "Caoutchouc" that "it seems to occur in all members of the Corymbosæ and Angophora," and also records it in *E. stricta*, stating that it is possible that it may be found in other species of Eucalyptus.

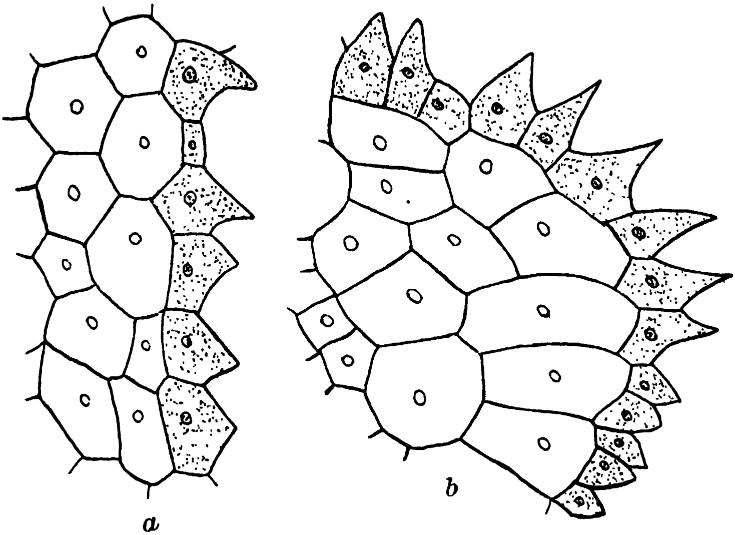
In this investigation an elastic epidermal covering was found in the following species:—

Angophora lanceolata Cav.
A. intermedia DC.
A. Bakeri C. Hall
Eucalyptus calophylla R.Br.
E. citriodora Hook.
E. corymbosa Sm.
E. dichromophloia F.v.M.
E. eximia Schau.
E. ficifolia F.v.M.
Eucalyptus intermedia Baker
E. maculata Hook.
E. peltata Benth.
E. santalifolia F.v.M.
E. terminalis F.v.M.
E. tesselaris F.v.M.
E. trachyphloia F.v.M.
E. Watsoniana F.v.M.

No rubber has been detected in *Angophora cordifolia.* With the exception of *E. santalifolia*, all the species of Eucalyptus enumerated above, are members of the Corymbosæ or Bloodwood group, or closely allied thereto.

It should be pointed out that even in the young shoots rubber is not always present, *e.g.* in a seedling of *E. citriodora* the young shoots were scabrous with numerous glandular hairs (fig. 3) which were persistent on the peltate leaves, but no evidence of rubber was found. In the case of normal shoots from a mature tree, however, the elastic secretion is undoubtedly present. Similarly in leaves of *E. trachyphloia*, glandular hairs are undoubtedly present, with an entire absence of rubber on the young shoots of seedlings, whereas in mature trees the normal foliage is glabrous and rubber occurs.

In an examination of sections of the leaf bud of *E. corymbosa* (fig. 1) it is found that marked papillose epidermal projections occur, (text figure (*a*) and (*b*)) which, however, do not develop in the very young leaves under about 0·3 mm. in diameter. The papillæ are very irregular in shape and size, often measuring up to 0·015 mm. in length, and are usually most prominent on the abaxial foliar surface particularly at the leaf margins and along the course of the



principal veins. They are often less marked on the adaxial surface in very young leaves where the epidermal cells are smaller.

In transverse sections of leaf buds of those Eucalypts in which rubber is not ordinarily detected, it is usual to find the leaves, even when of moderate size, in contact, the epidermal cells being more or less flat. In certain species such as *E. Smithii* or *E. Moorei* where the leaf margin is truncate the epidermal cells at that point are papillose. These projections mesh closely into the corresponding indentations in the opposing leaf margin, but there is no evidence of these cells secreting caoutchouc.

Both the inner and radial secretory epidermal walls of the rubber-bearing species are thin, in the young leaves, growth being due to free anticlinal division. The cells average about 0·013 mm. in diameter on the abaxial surface, and about 0·010 mm. on the opposite face, when in leaf bud. The protoplasmic contents are somewhat denser than in the adjoining parenchymatous tissue, but although small globules are often present, no definite evidence of oils or starch was found. One of the most conspicuous features of the epidermis is the presence of anthocyanin. In the young leaf buds this is not present, but as soon as the leaves separate, as a rule it is particularly prominent. It is not always confined to the epidermal cells, occasionally in young leaves it also occurs in the mesophyll to a depth of one or two rows of cells, and it is common to find it also in the supporting tissue of the vascular bundles. With the disappearance of the elastic covering, there is a greater development of chlorophyll in the mesophyll and a diminution in the amount of anthocyanin, though it is often present in the epidermis of older leaves which are apparently free from it. In leaves of *E. corymbosa* measuring 0·3 mm. in width, rubber was found to average 0·010 mm. in thickness, and was approximately evenly distributed on all surfaces. In slightly larger leaves measuring 0·8 mm. in width the secretion was found to be particularly thick, measuring up to 0·0185 mm. on the upper surface and 0·017 mm. on the under side. There is very little variation in thickness of the layer on the margin and mid-rib of very young leaves. In both the above cases the leaves were still in bud. The secretion becomes somewhat thinner in leaves as they expand from the bud, *e.g.* in a leaf 1·5 mm. in diameter, the thickness was 0·008 mm. on the under surface, somewhat thicker above, increasing to 0·018 mm. at the mid rib. In leaves 50 mm. in length the epidermal cells which contain anthocyanin measured 0·0185 mm. in depth, and the elastic covering was 0·01 mm. in thickness on the upper surface. In leaves 50 mm. in length, reddish in colour, the amount of the elastic secretion was practically wanting on the under surface except along the position of the vascular bundles and even many of the smaller lateral veins, but measured 0·009 mm. in thickness above. In a leaf of the same size but containing little anthocyanin and no elastic covering, chlorophyll being more marked, the outer epidermal wall measured 0·011 mm. in thickness above, *i.e.*, practically the same as that of the rubber-like secretion in the leaves already described. Similarly in mature leaves from the same branchlet, cuticular thickening of the epidermal cells averaged 0·008 to ·012 mm. in thickness.

The elastic membrane is readily removed from the epidermal cells beneath, and on examination is found to show the imprint of the papillose projections. Treatment with chloroform causes partial solution and some alteration in appearance, but there is a very definite insoluble residue, which still shows the imprint of the secretory cells. This residue is insoluble in all ordinary solvents such as alcohol, ether, acetone, etc., and was stained yellow with iodine and yellow-brown with iodine and sulphuric acid. It apparently resembles cutin. As pointed out by Smith, *l.c.*, there is undoubtedly a comparatively large quantity of wax present in the mature leaves, although there is no bloom such as occurs on the wax-bearing leaves of *E. cinerea*, etc. It therefore seems that there is a gradual transition from the elastic rubber like substance to the cutinised membrane, but with comparatively little alteration in thickness.

The great variation in thickness of the caoutchouc is shown by the following measurement of the leaves of *Angophora Bakeri;* at edges = 0·03 mm., abaxial surface = 0·004 – 0·01 mm. adaxial surface = 0·011 mm.

In the young leaves and stems on which rubber occurs, the outer surface of this layer is smooth, hence the glossy appearance. With the alteration of the rubber, the cuticle to some extent follows the outline of the epidermal cells beneath, becoming more or less papillose, but the epidermal projections are much less prominent than in the young foliage. Solereder(4) refers to the fact that these papillose cells make the foliar surface dull, and adds that they are rarer in the upper epidermis than in the lower. In the case of such species as *E. corymbosa* etc., however, the reverse is the case, the upper epidermis being decidedly more papillate.

A comparison was made between the loss of moisture from the leaves of *E. Sieberiana* and *E. corymbosa*, the former species not showing evidence of caoutchouc. A number of fresh leaves in different stages of growth were taken, the cut petioles being sealed with paraffin wax. These were weighed and exposed side by side to ordinary room temperatures, (about 15° C.) being protected from dust. They were again weighed after 24, 72 and 144 hours, the resultant percentage loss of moisture, calculated on the wet weight, being as follows:—

		24 hrs.	72 hrs.	144 hrs.
E. Sieberiana	(1)	43·6	50·9	52·7
	(2)	35·9	52·9	54·5
	(3)	23·3	54·6	56·5
	(4)	17·7	51·9	59·8
E. corymbosa	(1)	21·8	44·7	52·9
	(2)	29·8	54·0	57·2
	(3)	25·8	54·6	59·3
	(4)	30·4	56·1	59·4
	(5)	18·2	39·0	45·4

E. Sieberiana (1) Leaves 15 – 30 mm. long, anthocyanin present in epidermis. (2) Leaves 30 – 55 mm. long, anthocyanin present. (3) Leaves 55 – 80 mm. long. (4) Mature leaves.

E. corymbosa (1) Leaves 15 – 30 mm. long, caoutchouc present. (2) Leaves 30 – 45 mm. long, caoutchouc present but thinner than (1). (3) Leaves 45 – 80 mm. caoutchouc on upper surface and little or none beneath. (4) Leaves 45 – 80 mm. caoutchouc very thin or none. (5) Mature leaves. Anthocyanin present in (1) (2) and (3), little in (4), and none in (5).

Taking the youngest leaves of each species, the reduction of the moisture loss from 43·6% in *E. Sieberiana* to 21·8% in *E. corymbosa* after twenty-four hours is particularly striking. In the slightly older leaves of *E. corymbosa*, in which the elastic covering is thinner, it is found that the moisture loss is higher, but still much below that from the corresponding leaves of *E. Sieberiana.* In the latter species it is noticed that there is a steady drop in the amount of transpiration as the leaves become older, and the outer epidermal walls become thicker, whereas in *E. corymbosa* the loss, although smallest in the mature leaf, is very little less than in the youngest members. Similarly, after 72 hours the amount of desiccation is least, with the exception of the mature leaves of *E. corymbosa*, in the youngest leaves in which the rubber-like covering is most developed. After 144 hours the loss of moisture is practically equivalent in the young leaves of both species. The principal function of the caoutchouc is therefore probably to reduce transpiration in the very young leaves, and being elastic would stretch readily as growth proceeds.

In all species of Angophora so far examined the palisade mesophyll is confined to the upper surface only, and the stomata are on the abaxial surface. This is also characteristic of *E. corymbosa*, *E. calophylla*, *E. dichromophloia*, *E. ficifolia*, *E. intermedia*, *E. trachyphloia*, *E. hœmatoxylon*, whereas the other species such as *E. maculata*, *E. eximia*, *E. peltata*, *E. tesselaris*, the leaves are isobilateral, yet the elastic substance is thicker on the upper surface.

In *E. tesselaris*, rubber was found in leaves up to 15 mm. in length, larger leaves up to 30 mm., were glossy, but no trace of an elastic substance was observed. In the case of *E. santalifolia*, only a trace of rubber was found. A leaf 20 mm. in length was 0·37 mm. in thickness, and on the upper surface was a thin elastic layer, but practically nothing was observed on the abaxial surface. In slightly more mature foliage there is a marked glossiness, becoming less so in older leaves which are coriaceous and isobilateral, with a thick cuticle.

Haberlandt(5) advances the theory that the "lens action of epidermal papillae is primarily connected with the perception of photic stimulae." Stahl(6) has also advanced the theory that the papillose projections enable the plant to absorb oblique rays of light which would otherwise be lost. It seems obvious that neither theory explains the presence of the papillae in cases of the nature described above. It seems probable that they act, apart from their secretory functions, as pegs holding the elastic covering, particularly as they are well developed on the leaf margins and mid-rib, moreover they are not usually found, except in certain cases at the leaf margins, in species in which caoutchouc does not occur.

Summary.

Secretory epidermal cells occur in a number of species of Eucalyptus and Angophora, those species of the former genus which secrete caoutchouc being practically confined to the Corymbosæ. The epidermal cells are marked by papillose projections which may act to some extent as pegs.

The elastic secretion is especially prominent on the young leaves and stems while still in bud, measuring up to 0·018 mm. in thickness, but disappears in older leaves, remaining longest on the adaxial foliar surface.

It is partly soluble in chloroform, but a residue is left which resembles cutin, and there is evidently a gradual change from the elastic rubber-like layer to the inextensible cuticularised epidermal wall of the mature leaf, which also contains a wax.

The elastic covering acts as a very efficient check against transpiration, and this is probably the primary function of the secretion.

I am indebted to Mr. J. H. Maiden, I.S.O., F.R.S., and to Mr. H. G. Smith, F.C.S., for some of the material used in this investigation.

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Explanation of Plates and Text Figure.

Plate XIII.

Fig. 1. Transverse section of portion of a leaf bud of *Eucalyptus corymbosa* Sm. showing papillose epidermal cells, particularly marked on the abaxial foliar surfaces. The innermost sections are in contact. showing that the elastic covering has not yet been secreted. In the outer leaves this secretion is not prominent owing to the rubber having been dissolved to some extent in the preparation of the sections, but a slight trace can still be seen. × 80.

Fig. 2. Transverse section of leaf bud of *Eucalyptus maculata* Hook. It is possible to detect traces of the elastic covering on the leaves, particularly on the outer surfaces. × 80.

Plate XIV.

Fig. 3. Transverse section of leaf bud from seedling of *Eucalyptus citriodora* Hook. There is an entire absence of any elastic epidermal secretion in this case, but numerous glandular hairs are present, some of which are shown cut more or less transversely, near the actual leaf sections. In the normal foliage rubber occurs in the young leaf buds. × 35.

Text Figure 1.

(*a*) Portion of transverse section of petiole of *Eucalyptus corymbosa* showing papillose epidermal projections. × 700.

(*b*) Portion of transverse section of margin of young leaf of *Eucalyptus corymbosa* showing very prominent epidermal papillæ. × 700.

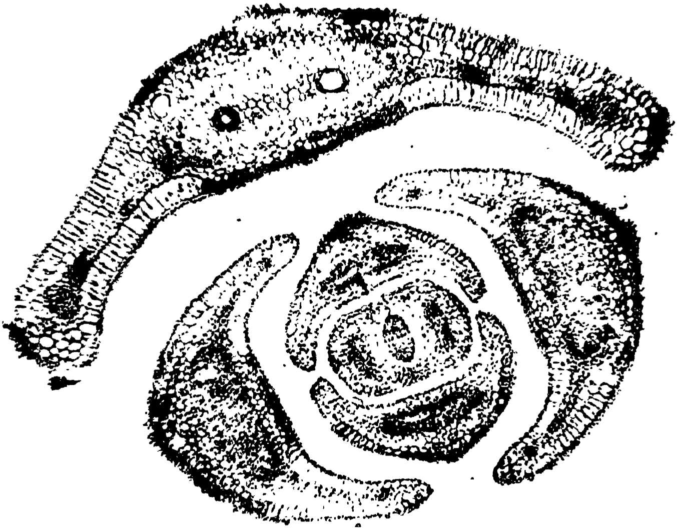

Fig. 1.

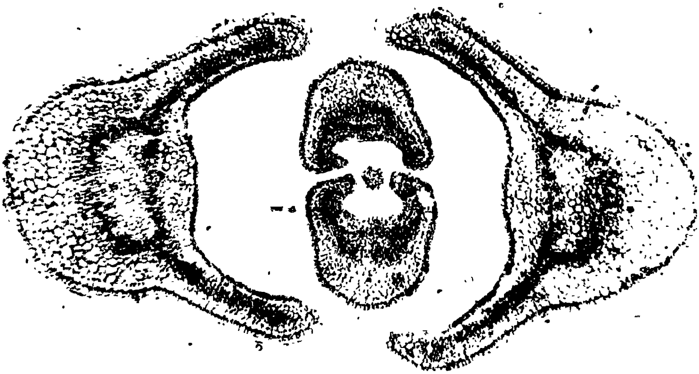

Fig. 2.

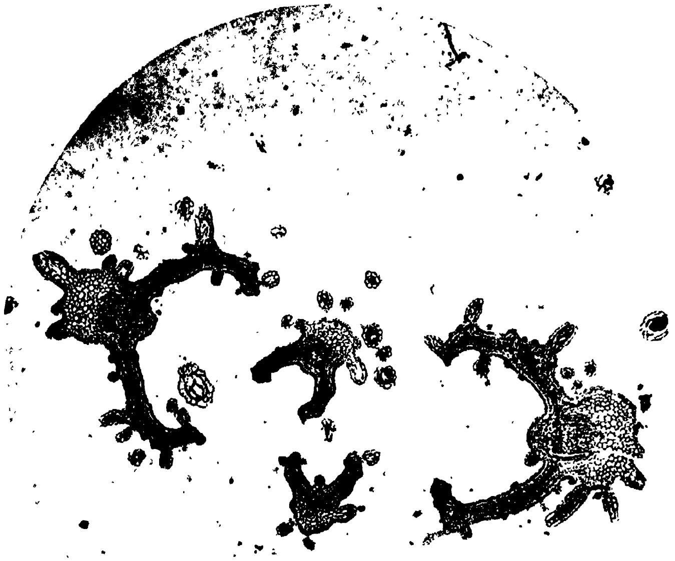

Fig. 3.

NOTE ON THE EFFECT OF TEMPERATURE ON BORERS ATTACKING SEASONED AND UNSEASONED TIMBER

(WITH SPECIAL REFERENCE TO THE FURNITURE BEETLE *Anobium striatum*).

By M. B. WELCH, B.Sc.,
Technological Museum.

[*Read before the Royal Society of N. S. Wales, October 3, 1923.*]

AT the present time the borer problem is of great importance, and it is thought that the following results of an investigation into one method of eradication which has proved successful might be of interest. The usual method of treatment is by painting or spraying the timber with some deterrent liquid. It was found that in many soft woods particularly the softer pine timbers, as New Zealand White Pine (*Podocarpus dacrydioides*), the penetration of the most efficient liquid used was effective possibly up to an inch under ordinary conditions of application, whereas in sound hardwoods, as Eucalyptus spp., the degree of penetration was extremely low, except where sun cracks or crevices of any kind allowed the liquid to enter more freely. This penetration in sound hardwood was found to be only from $\frac{1}{16}''$ to $\frac{1}{8}''$, except on end grain, where the vessels, being cut transversely, offered a readier means of entry, unless they are blocked by an ingrowth of thin walled parenchymatous tissue or tyloses, which is by no means infrequent.

It is thus obvious that even in moderate sized timber, the degree of penetration is not sufficient to assure the efficacy of any liquid deterrent. To make sure that certain affected timber specimens in the Technological Museum which had been attacked by the Furniture Beetle (*Anobium *striatum)* and the Powder Post Beetle *(Lyctus brunneus)* were freed from the boring insects, they were subjected to a process of steaming in a large digester for several hours. Although twelve months have elapsed since the treatment was applied there has been no recurrence of the trouble. It must be understood, however, that steaming does not render the timber immune from further attack, and a subsequent poisoning treatment was given which it is hoped will prevent any further ravages.

Altson[1] mentions the use of temperature of 70° for two hours, giving an extra hour for each additional inch of timber above 1″, as an effective remedy for the borer, but so far as could be determined no test has been made as to the actual temperature which was fatal to both beetles and larvæ. For this reason a number of tests were made at different temperatures, exposing both beetles and larvæ for different periods of time to a moist atmosphere, such as would be set up during steaming. It was soon found that a comparatively low temperature for a short time is sufficient to kill the insects. The results obtained being as follows:

Anobium striatum.	No.	Temp. °C.	Time in Seconds.
Larvæ	6	44	60
	2	43	60
	3	46	30
	6	46	60
	5	45	120
Beetles	1	42	50
	2	45	22
	4	46	30
	4	46	60
	5	45	120

In each case a number of the larvæ or beetles were introduced into a moist atmosphere at a temperature of 42 –

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[1] Beetles Damaging Seasoned Timber, 1922. W. Rider & Son, London.

46° C. and after exposure for the length of time given in the third column, were removed to atmospheric temperature and placed under observation for some days. In no case was any life detected subsequently, thus indicating that, in this particular series of experiments, possibly a slightly higher temperature was used than was absolutely necessary.

Similar experiments carried out with the larvæ and beetles of the Powder Post Beetle *(Lyctus brunneus)* also showed that a temperature of 45° C. for approximately 60 seconds was in most cases fatal.

Since both these borers attack only seasoned timber and as both, but in particular the Furniture Beetle, cause considerable damage to furniture, experiments were made with the object of determining the time occupied in raising the internal temperature of wood of dimensions such as are used in cabinet work to 45° C., when exposed to air at temperatures not greatly in excess of this.

A piece of Queensland Maple *(Flindersia Chatawaiana)* 3″ × 3″ × 12″ was exposed to an air temperature of 50° C. After two hours the internal temperature reached 45° C. A similar piece in air at a temperature of 60° C. reached an internal temperature of 45° C. in one hour. Since at these temperatures french-polish is not affected, it should furnish a ready means of treating small articles, although as already pointed out, it does not render the timber free from risk of reinfestation.

The Shot-hole Borers, of which the principal are *Platypus* spp. and *Xyleborus* spp., cause very serious damage to unseasoned timber, especially to logs before cutting. These pin-holes in constructional timber are not detrimental to any great extent, but in cabinet timbers depreciate the value of the wood by over fifty per cent. At the present time a firm of timber merchants in Sydney is treating its logs with live steam in a wooden digester practically at atmospheric pressure, and it is claimed that the method is efficacious in exterminating the borer. In an examination I have made of the affected logs after treatment, no evidence of live borers was found. The exposure of timber to these temperatures for several hours is not sufficient to influence the strength of the material. Not only are the Shot-hole Borers destroyed, but also any Powder Post Borers, if present, though obviously the timber is not rendered immune from future infestation. Tests made under similar conditions to those applied to the Furniture Beetle have shown that a temperature of 47° C. for one minute produced fatal results to both the beetles and larvæ. No direct tests were made of the degree of heat capable of being sustained by the eggs, but since no insects have developed in timber already treated, it seems probable that they too were destroyed. Since the log retains sufficient moisture to enable these Shot-hole Borers to work for a considerable time, the damage varies directly as the length of time between infestation and conversion, whereas by early steaming a large amount of the damage can be unquestionably avoided.

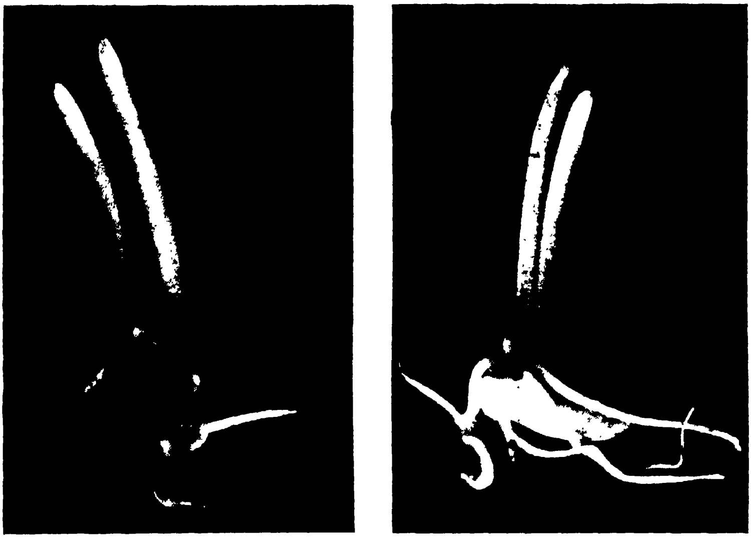
Summary.

The application of heat to both seasoned and unseasoned timber affected with borers has proved a most efficient remedy for the trouble.

Exposure of both larvæ and beetles of the Furniture Beetle *(Anobium striatum)* to a comparatively low temperature of about 45° C. for one minute in moist air, has in the majority of cases proved fatal.

The treatment can be successfully applied to logs, sawn timber, and smaller made-up articles.

Similarly, it has been found that the Powder Post Beetle and the Shot-hole Borers are unable to sustain temperatures of about the same order.



Photograph of germinating grain of "Federation" wheat having two embryos. × 2.

NOTE ON THE OCCURRENCE OF DOUBLE EMBRYOS IN WHEAT GRAINS.

By W. L. WATERHOUSE.

The University of Sydney.

With Plate XV.

[*Read before the Royal Society of N. S. Wales, October 3, 1923.*]

IN the course of investigations dealing with rust in wheat, very many germinations of wheat grains of different varieties are being carried out.

In June 1923, amongst young seedlings of the variety of *Triticum vulgare* known as "Yandilla King," one was noticed in which two plumules very close together were emerging from the soil. The young plant was removed from the pot and examined. Both shoots arose from a single wheat grain. There were present six seminal roots. The plant was photographed and then replanted.

Shortly afterwards, Mr. H. J. Hynes, Walter and Eliza Hall Agriculture Research Fellow of this University, found a second case of this nature. In germinations of the variety of *Triticum vulgare* known as "Federation," one grain was present from which two shoots and six seminal roots arose (Plate XV). It was photographed and then replanted.

No attempt was made in either case to cut sections in order to determine the relation of the parts in these seedlings. It was thought to be more important to try and grow the plants to maturity. Both plants are growing in an apparently normal manner, and it is hoped that they will mature grain and thus make possible a genetical study of this double embryo character.

The seed of both the varieties was pure line seed supplied by Mr. J. T. Pridham of the N.S.W. Department of Agriculture. It was grown and harvested at Cowra in 1921.

The occurrence of two embryos in a wheat grain is apparently rare. It was not expected that so soon after finding the first, the second would appear. It is an occurrence which will doubtless supply a full explanation of certain cases in which it has been stated that from a single grain of wheat, two distinct kinds of ears have developed. For this reason it has been deemed worthy of record before the genetical behaviour of the two individuals can be reported.

METHOD OF COMPUTING THE TRUE ANOMALY IN AN ELLIPTICAL ORBIT FROM VALUES OF THE MEAN ANOMALY.

By C. J. MERFIELD, F.R.A.S.

(Communicated by J. NANGLE, F.R.A.S.)

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WHEN preparing an ephemeris of a celestial object from elliptical orbit elements, the general procedure is to find "E," the eccentric anomaly from the well known equation

$$M = E - e \operatorname{Sin} E.$$

or some formula depending on it.

If we are computing an ephemeris giving values of "α" and "δ," say at four day intervals, it becomes a simple matter to estimate a value of "E," after three or four values have been obtained, from which a correct value may be found by a process, not necessary to explain here.

The solution of the above transcendental equation may be avoided by preparing a table of "M" with the argument "E." From such a table the angle "E" corresponding to a given value of "M" may be interpolated.

The true anomaly and radius vector may be found from

$$\sqrt{r} \operatorname{Sin} \tfrac{1}{2} v = (\operatorname{Sin} \tfrac{1}{2} E) \sqrt{a (1 + e)}$$

$$\sqrt{r} \operatorname{Cos} \tfrac{1}{2} v = (\operatorname{Cos} \tfrac{1}{2} E) \sqrt{a (1 - e)}$$

in which "r" represents the radius vector, "v" the true anomaly, "a" the semi-axis major and "e" the eccentricity of the ellipse.

The calculation of a table of the values of "E" can be avoided by the following method, and the true anomaly determined from "M." For we have

$$M = \int \frac{r^2}{a^2} \frac{d\,v}{\sqrt{1-e^2}} \cdot \qquad \frac{r}{a} = \frac{1-e^2}{1+e\,\text{Cos}\,v}.$$

$$M = (1-e^2)^{\frac{3}{2}} \int_0^v \frac{d\,v}{1+e\,\text{Cos}\,v} \quad \ldots \quad \ldots 1$$

$$= \tan^{-1} \frac{\text{Sin}\,v\sqrt{1-e^2}}{e+\text{Cos}\,v} - \frac{\text{Sin}\,v\sqrt{1-e^2}}{\frac{1}{e}+\text{Cos}\,v} \ldots 2$$

For numerical computation this equation (2) will be better in the following form

$$M = \text{Sin}^{-1} \frac{\text{Sin}\,v\sqrt{1-e^2}}{e(\frac{1}{e}+\text{Cos}\,v)} - \frac{\text{Sin}\,v\sqrt{1-e^2}}{(\frac{1}{e}+\text{Cos}\,v)} \ldots 3$$

$$r = \frac{a\,(1-e^2)}{e(\frac{1}{e}+\text{Cos}\,v)} \quad \ldots \quad \ldots \quad \ldots 4$$

The angle represented by the first term of equation (2) or (3) may be taken numerically less than ± 180 and will be in the same quadrant as "v." The second term must be multiplied by the value of the radian.

If a table be prepared from either equation (2) or (3) with the given values of "e" and "v," the latter being taken at equal and suitable intervals, between the limits desired, then the true anomaly can be readily interpolated for values of "M."

Should "E" be required for any purpose it may be found from the equation

$$\tan \tfrac{1}{2} E = \sqrt{\frac{1-e}{1+e}} \tan \tfrac{1}{2} v \ \ldots \quad \ldots \quad \ldots 5$$

It is to be noted that the first term of (2) or (3) represents the angle "E."

When preparing an ephemeris from elliptical orbit elements, the method here presented, will be found exceedingly expeditious; a table of "M" is rapidly prepared.

Example.

$$
\begin{array}{rrl}
v = 70^\circ & \text{Log } e = & 9·4771213 \\
 & \text{Log } (1-e^2) = & 9·8590414 \\
 & \tfrac{1}{2} \text{ ,, } (1-e^2) = & 9·9795207 \\
 & \text{,, } 1/e \quad = & 0·5228787
\end{array}
$$

Equation (3)

$$
\begin{array}{rl}
\text{Log Cos } v = & 9·5340517 \\
\text{,, } 1/e \quad = & \left.\begin{array}{l} 0·5228787 \\ 0·9888270 \\ 0·0424204 \end{array}\right] \\
\text{Zechs Table} = & \\
\text{Log } \left(\frac{1}{e} + \text{Cos } v\right) = & 0·5652991 \\
\text{,, Sin } v\sqrt{1-e^2} = & 9·9525065 \\
 & 9·3872074 \\
\text{Log first term} = & 9·9100861 = 54\overset{\circ}{·}38925 \\
\text{,, second ,,} \quad = & 1·1453300 = \underline{13·97430} \\
\text{Log } r/a = & 9·9166210 \quad 40·41495 = M.
\end{array}
$$

The following short table has been prepared with a value of log e equal to 9·5697643 and "v" between the limits 40 degrees and 60 degrees, every fourth value being calculated. The values for the remaining arguments being determined by using Bessel's formulæ for systematic interpolation to halves.

Log e = 9·5697643.

v°	M °	$10^4 \dfrac{dM}{dv}$	$10^4\, \tfrac{1}{2} \dfrac{d^2M}{dv^2}$
43	19·2721	+ 4951	17·0
44	19·7689	4986	17·5
45	20·2693	5022	18·5
46	20·7732	5059	19·0
47	21·2810	5097	19·0
48	21·7926	5136	19·5
49	22·3081	5176	20·5
50	22·8277	5217	21·0
51	23·3515	5260	21·5
52	23·8796	5303	22·5
53	24·4122	5348	23·0
54	24·9492	5394	23·5
55	25·4909	5441	23·5
56	26·0373	5489	24·5

$$\begin{aligned} \text{Say } M &= 24^\circ\ 20'\ 50''\cdot 9 = 24^\circ\cdot 34747 \\ v &= 52^\circ + \frac{4678\cdot 7}{5323} = 52^\circ\cdot 87896 \\ &= 52^\circ\ 52'\ 44''\cdot 3 \\ E &= 37^\circ\ 12'\ 55''\cdot 26 \end{aligned}$$

Oppolzer's values being 52° 52′ 44″·5 and 37° 12′ 55″·3.

This table includes values of "M" given in Oppolzer's 'Lehrbuch zur Bahnbestimmung der Kometen und Planeten' page 392 or page 401 of the French translation.

In a similar manner all the values of "v" tabulated by Oppolzer can be found from the above table.

Very useful are the 'Tables de Mouvement Képlérien' par M. F. Boquet. I have only seen the first part, which contains values of "M" and log r/a for "e" between 0·00 and 0·49.

For many purposes these tables expedite the calculation of the true anomaly and radius vector. When greater accuracy is required, then the method here given will be found exceedingly expeditious. It materially reduces the numerical work in the calculation of an ephemeris from elliptical orbit elements. It has been used by the writer for some time past with much success.

M. Boquet's tables have been prepared from equation (1) by mechanical integration. Apparently the same process was used in finding values of log r/a from the equation

$$d \log \frac{r}{a} \Big/ d v = \operatorname{Sin} v \Big/ \left(\frac{1}{e} + \operatorname{Cos} v\right)$$

which can hardly be commended, for we have

$$\begin{aligned} \log r/a = \int \frac{e \operatorname{Sin} v}{1 + e \operatorname{Cos} v}\, d v &= \log \frac{(1-e^2)}{1 + e \operatorname{Cos} v} \\ &= \text{,,}\ \frac{(1-e^2)}{e\left(\frac{1}{e} + \operatorname{Cos} v\right)} \end{aligned}$$

If values of "v," accurate to within two or three seconds of arc, are sufficient then the tables of M. Boquet can be used with confidence. The interpolation is complex as for most tables of double entry.

THE ESSENTIAL OIL OF DARWINIA GRANDIFLORA AND THE PRESENCE OF A NEW ACETIC ACID ESTER.

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THE botany of this tall erect shrub has been fully described by Messrs. Baker and Smith in the Journal of the Royal Society of N.S.W., Vol. L, (1916), pages 181–183. The distribution of the plant as then given was Berowra (R. T. Baker) and left bank of the Hawkesbury River opposite Milson Island (Dr. J. B. Cleland), since when it has been found in quantity in the upper reaches of Middle Harbour (M. B. Welch), and on the rocky ledges and in the ravines on the steep sides of the creeks at Narrabeen, near Sydney (A. R. Penfold). In this connection see also paper by E. Cheel entitled "Notes on the genera *Darwinia*, *Homoranthus* and *Rylstonea* in N.S. Wales, Queensland, and South Australia," published in the Journal of the Royal Society of N.S.W., Vol. LVI, (1922) pages 74-75. The trees at Middle Harbour were apparently of good age and about 15 feet in height, whilst the shrubs at Narrabeen were of more recent date and luxuriant growth. This shrub appears to be making its appearance in places around Sydney where it has not previously been observed.

The essential oil of this plant was obtained by the writer in July 1916, and although the quantity of oil available was insufficient for a satisfactory examination, still it was observed that the fractions obtained on distillation possessed high optical activity, especially the one boiling at

225–235° C. suspected of containing geraniol. It was decided to await further supplies of material when other localities had been discovered in order to pursue the observation. Meanwhile, Messrs. Baker and Smith in raising the plant to specific rank (it was then *D. taxifolia* var. *grandiflora*, Bentham) obtained material from Berowra in November 1916 and described the essential oil thereof in December, 1916 (*l.c.*, pages 183–186). Since that date the other two more extensive patches of the shrub at Middle Harbour and Narrabeen had been observed; these presented an opportunity for a more thorough examination of the essential oil, with the result that considerable data is now available respecting the chemistry of this interesting Myrtaceous shrub. The percentage yield of oil was found to be not less than 0·3%, varying up to 0·5% from plants obtained from more favourable situations (Baker and Smith found only 0·12), and whilst the presence of pinene has been confirmed, the writer was unable to prove that geranyl acetate was present, although suspected by Messrs. Baker and Smith on account of the ester being saponified by two hours contact in the cold, but which they were unable to confirm through lack of material. Their reasoning too seemed quite logical, especially as *Darwinia fasicularis*, a closely allied species, contains 60% geranyl acetate, and it has been the custom when dealing with essential oils of the Myrtaceæ to consider an ester saponifiable by alcoholic potash solution at room temperature with two hours contact as geranyl acetate. Close investigation, however, has shown, that whilst geranyl acetate may be present in small quantity, the principal ester saponifiable by alcoholic potash solution with two hours contact in the cold is the acetic acid ester of a highly dextro-rotatory alcohol closely resembling verbenol, which for the present is named DARWINOL, until such time as its identity is established or otherwise. This observation renders it imperative for the alcohols to be separated and identified in all future examinations of essential oils containing acetic acid esters saponifiable at room temperature. Repeated fractional distillation of the terpenes revealed the presence of another, other than pinene, boiling at 175 - 177° C., which it has not yet been possible to identify. It yielded a dihydrochloride melting at 53—54° C., but insufficient was available for a thorough investigation, but as it has apparently been found in greater quantity in another essential oil at present under examination, its chemistry will be more fully investigated in conjunction therewith, and made available at a later date.

One would have preferred before publication to have proceeded further with the chemistry of the ester and determined the constitution of the alcohol, but the area at Middle Harbour where the most extensive patch existed was completely burnt last summer, just after the collection of the 521 lbs. of material; here again, unfortunately, on account of the drought prevailing the ester content was lower than that of any other collection. Considerable time must necessarily elapse before more material is available.

Essential Oil.

Leaves and terminal branchlets for distillation were procured from Berowra (28 miles north of Sydney), Middle Harbour and Narrabeen, near Sydney, at various periods, and were quite fresh when distilled. The oils in every instance were of a pale lemon colour, quite mobile, with a pronounced terpenic odour, followed by a secondary one of the ester. Altogether 1,165 lbs. weight of leaves and terminal branchlets, cut as for commercial distillation, were distilled, with an average percentage yield of oil of 0·35%.

The principal constituents, so far identified, were found to be *d*-α-pinene, an unidentified terpene of boiling point

175 – 177° C., an acetic acid ester not hitherto described, called darwinol acetate, a sesquiterpene and corresponding sesquiterpene alcohol, a stearoptene of M.Pt. 103 – 104° C. (probably a phenol ether), and small quantities of isovaleric aldehyde, amyl alcohol, and an ester.

Experimental.

The leaves and terminal branchlets collected yielded on distillation with steam, crude oils, possessing the chemical and physical characters, as shown in table:—

Date.	Locality.	Weight of Leaves.	Yield of Oil.	Specific Gravity $\frac{15}{15}$° C.	Optical Rotation.
23/7/1916	Berowra	40 ℔s.	0·3%	...	...
15/9/1921	Narrabeen	84 ℔s.	0·37%	0·9082	+ 27·65°
14/12/1921	Middle Harbour and Berowra	80 ℔s. 108 ℔s.	0·34%	0·9165	+ 22·22°
16/8/1922	Narrabeen	20 ℔s.	0·49%	0·9106	+ 25·85°
23/10/1922	Middle Harbour	521 ℔s	0·30%	0·9013	+ 18·25°
7/12/1922	Narrabeen	121 ℔s.	0·4%	0·9164	+ 27·20°
19/5/1923	Narrabeen	191 ℔s.	0·3%	0·9121	+ 24·50°

Refractive Index 20° C	Solubility in 80% alcohol.	Ester No. cold 2 hours.	Ester No. hot 1½ hours.	Ester No. after acetylation cold	Ester No. after acetylation hot
[Constants taken on fractions only (*i.e.*, first hour, second hour, etc.)]					
1·4739	1 in 4½ vols.	93·42	94·69	117·34	130·55
1·4805	1 „ 7 „	79·32	80·4	100·61	126·86
1·4750	1 „ 5 „	92·34	95·13	...	126·34
1·4798	1 „ 10 „	63·63	66·81	71·66	86·92
1·4778	1 „ 7 „	97·04	99·36	...	122·74
1·4782	1 „ 9 „	86·12	86·87	97·4	114·56

The following oils were examined in detail, viz:— 14/12/1921 (Middle Harbour and Berowra) and 23/10/1922 (Middle Harbour); of the former, 300 c.c. crude oil were treated with alcoholic potash solution at room temperature to decompose the ester, when subsequently 265 c.c. of oil were recovered, and distilled at 10 mm.:—

Table "A."

Boiling Point	Volume	Specific gravity $\frac{15^\circ}{15}$ C.	Optical rotation	Refractive index at 24° C.
63 - 66 ° C.	74 c.c.	0·8615	+ 30·2°	1·4661
66 - 77·5 „	30 „	0·8615	+ 21·25°	1·4670
78 - 82·5 „	20 „	0·8618	+ 10·1°	1·4735
83 - 112 „	16 „	0·9318	+ 21·1°	1·4859
112 - 118 „	6 „	...	...	...
118 - 121 „	52 „	0·9444	+ 25·0°	1·4931
residue	67 „			

With the latter (23/10/1922), it was decided to distil the crude oil, as obtained, at 10 mm. in order to obtain the ester in as concentrated a condition as possible. Accordingly 660 c.c. were repeatedly fractionated at 10 mm. with the following final result:—

Table "B."

No.	Fraction	Quantity	Optical rotation	Refractive index, 20° C.	Ester No. cold, 2 hours
1	50- 60°C, 10 mm.	200 c.c.	+ 23·85°	1·4697	...
2	60–105 „	160 „	+ 13·65°	1·4735	...
3	105–110 „	25 „	+ 21·15°	1·4820	...
4	110–119 „	74 „	+ 25·25°	1·4808	177
5	120–125 „	83 „	+ 21·55°	1·4864	147
6	125–145 „	55 „	+ 13·1°	1·4966	45·7
7	145–156 „	20 „	+ 12·2°	1·4967	34·5
	residue				

Determination of Terpenes.—14/12/1921. The three main fractions (Table "A") boiling from 63° C. to 82·5° C. at 10 mm. (124 c.c. in all) were repeatedly distilled under reduced pressure and finally at 769 mm. with the following result:—

Table "C."

Fract. No.	Boiling Point	Volume	Spec. gravity $\frac{15^\circ}{15}$ C.	Optical rotation	Refractive index, 20° C.
1	156 - 158° C.	23 c.c.	0·8617	+ 36·75°	1·4659
2	158½ - 160 „	15 „	0·8621	+ 35·00°	1·4670
3	160½ - 166 „	28 „	0·8614	+ 30·72°	1·4690
4	166½ - 170 „	8 „	0·8599	+ 22·25°	1·4717
5	170 - 176 „	20 „	0·8583	+ 11·80°	1·4750
6	177 - 182 „	16 „	0·8583	+ 5·5°	1·4769

d-α-pinene.—Confirmation that fractions Nos. 1 and 2 consisted essentially of *d-α*-pinene was obtained by shaking 32 c.c. with 67 grams powdered potassium permanganate, 800 c.c. water and 450 grams ice until the reaction was completed. On removal of manganese sludge, the liquid was steam distilled to remove unchanged terpene, and evaporated to a small bulk. It was then acidulated with dilute sulphuric acid solution and extracted with chloroform. On removal of solvent about 15 grams pinonic acid were obtained distilling at 176 – 182° C. at 5 mm., which readily solidified on standing overnight. The crystals were separated and purified from petroleum ether when they melted at 70° C. The semicarbazone prepared therefrom melted at 207° C. 0·2504 gram of the acid in 10 c.c. chloroform gave $[\alpha]_d$ 20° C. + 92°.

Negative examination for other terpenes.—Fraction No. 3 was tested for β-pinene without result, whilst Nos. 5 and 6 yielded negative results when examined for phellandrene, sylvestrene, terpinene, and dipentine. In fact every fraction on oxidation with potassium permanganate gave varying amounts of pinonic acid recognised by its semicarbazone, melting point 207° C.

The evidence pointed strongly to the presence of another terpene, not unlikely olefinic, but it could not be isolated in a condition of purity, although it was apparently concentrated in those fractions distilling at 174 – 182° C. A further attempt to isolate it in a purer condition was made by repeated fractional distillation of the lower boiling fractions of consignment 23/10/1922 (Table "B") which was much higher in content of terpenes. The following table "D" enables its concentration to be followed:—

Table "D."

Fraction	Volume	Spec. gravity 15/15° C.	Optical rotation	Refractive index, 20°C.
57 - 58° C. at 20 mm.	28 c c.	0·8623	+ 32·00°	1·4659
58 - 61 „	46 „	0·8617	+ 29·85°	1·4668
61 - 65 „	49 „	0·8603	+ 25·50°	1·4686
65 - 68 „	65 „	0·8589	+ 20·80°	1·4702
166 - 171°C. at 763 mm.	12 „	0·8572	+ 17·15°	1·4725
171 - 174 „	15 „	0·8545	+ 6·15°	1·4764
174 - 177 „	51 „	0·8513	+ 2·45°	1·4770

Other terpene.—The terpene, represented by fraction distilling at 174 – 177° C., 51 c.c., on examination failed to yield any of the ordinary crystalline derivatives characteristic of such bodies, beyond a mixture of hydrochlorides when treated with dry hydrochloric acid gas in dry ether solution. On prolonged exposure and cooling a solid dihydrochloride was finally obtained, which when purified from ethyl alcohol melted at 53 – 54° C. The small optical rotation shown by the fraction is probably due to contamination with *d*-α-pinene, the pure terpene undoubtedly being quite inactive.

Determination of ester (saponifiable with alcoholic potash solution with two hours contact at room temperature). The fractions of oil boiling at 110 – 119° C. and 120 – 125° C. at 10 mm. (Table "B") of ester No. 177 and 147 respectively, were mixed and subjected to repeated fractional distillation at 10 mm., when the following fractions were obtained:—

Volume	Boiling point at 10 mm.	Spec. gravity 15/15° C.	Optical rotation	Refractive index, 24½°C.	Ester No. cold 2 hours
36 c.c.	108 – 113°C.	0·9672	+ 30·5°	1·4742	216·2
28 „	113½–116 „	0·9637	+ 27·5°	1·4770	204·3

It was not possible to concentrate the ester to a greater extent on account of the tendency to form constant boiling mixtures with the sesquiterpene and other bodies present in the crude oil. The two fractions were accordingly mixed, and the ester hydrolysed by means of alcoholic potash solution at room temperature for two hours, and the acid and alcohol portions separately examined:—

Acid.—The potash salts were separated, decomposed with dilute sulphuric acid solution and steam distilled. The volatile acids thus obtained were neutralised by means of ammonia solution and the silver salt prepared therefrom. 0·7784 gram yielded on ignition 0·5004 gram silver = 64·29%. (The silver salt of acetic acid yields 64·67% silver). The potash and ammonium salts on examination gave all the ordinary qualitative tests for acetic acid. The principal acid of the ester is, therefore, acetic acid.

Alcohol.—The crude alcohol separated after saponification of the ester was repeatedly distilled at 10 mm. when it was obtained in as pure a condition as possible by fractional distillation. A portion of same was purified through the phthalic acid compound. As thus obtained it was a colourless, somewhat viscous liquid, of pleasant odour, strongly suggestive of geraniol, but somewhat finer and less sweet. It combined very slowly and with difficulty with phthalic anhydride, and not at all with anhydrous calcium chloride (*i.e.*, under the same conditions that combination is effected with geraniol).

Its chemical and physical characters were determined to be:—

Boiling point at 10 mm. ...	108 – 111° C.
Specific gravity, 15/15° C. ...	0·9559
Optical rotation	+38·6°
Refractive index, 20° C. ...	1·4918

The results of combustion determinations were unsatisfactory, the figures for hydrogen being on the low side, but those obtained with the derivatives left no doubt at all as to the formula of the alcohol.

(1) 0·1083 gram gave 0·3082 gram CO_2 and 0·1080 gram H_2O
C—77·62%, H—11·08%.

(2) 0·1274 gram gave 0·3622 gram CO_2 and 0·1268 gram H_2O
C—77·53%, H—11·06%.

(3) 0·1021 gram gave 0·2926 gram CO_2 and 0·1016 gram H_2O
C—78·15%, H—11·05%.

$C_{10}H_{18}O$ requires C—77·92%, H—11·69%.

Molecular weight determination.—A molecular weight determination by the Landsberger boiling point method, using acetone as solvent, gave the following result—

1·2954 grams in 31 c.c. acetone elevated the boiling point 0·6°. M.Wt. = 154·6. $C_{10}H_{18}O$ requires 154.

Phthalic acid ester.—This derivative was obtained by heating the alcohol with phthalic anhydride between the temperatures of 98° C. and 120° C. for a considerable period. Combination was very slow and imperfect, and the alcohol was easily decomposed if the temperature exceeded 120° C. The derivative, however, was obtained in white crystals, sparingly soluble in petroleum ether from which it was purified. It melted at 107 - 108° C.

Napthylurethane.—On allowing equimolecular weights of the alcohol and napthylisocyanate to remain in contact for several weeks combination was effected. On purification from ethyl alcohol it melted at 86 - 87° C.

0·1020 gram gave 0·2902 gram CO_2 and 0·0694 gram H_2O
C—77·59%, H—7·56%.

$C_{10}H_7\,NHCOOC_{10}H_{17}$ requires C—78·02%, H—7·74%.

Phenylurethane.—The writer was not successful in obtaining a derivative by the use of phenylisocyanate.

Oxidation.—On treatment of 20 c.c. alcohol with Beckman's chromic acid solution a small quantity of ketone was obtained, together with an acid or mixture of acids which readily formed a chromium compound. The former which possessed an odour much resembling menthone was purified by combining it with neutral sulphite solution and regenerating same by means of caustic soda solution, and finally steam distillation. It had optical rotation of +24° and refractive index, 20°C. 1·5008. It readily yielded a semicarbazone, which on purification from ethyl alcohol melted at 217 - 218° C. This derivative on combustion gave the following result:—

0·1126 gram gave 0·2602 gram CO_2 and 0·0912 gram H_2O
C—62·98%, H—9·00%.
$C_{11}H_{19}N_3O$ requires C—63·15%, H—9·09%.

The ketone therefore appears to possess the formula $C_{10}H_{16}O$. Although the alcohol boils at the same temperature as geraniol and resembles it in some respects, its physical characters and general chemical deportment readily differentiate it therefrom.

Determination of total combined acids.—A small quantity of an oily acid appeared to be present in combination as an ester, as in the working up of the various fractions containing ester, the mixed potash salts on treatment with dilute sulphuric acid solution and steam distillation yielded oily droplets floating on the surface of the aqueous distillate. These oily globules were filtered off through a moist filter paper, neutralised with ammonia solution, when the silver salt prepared therefrom was found to contain 33·65% silver. The aqueous distillate, freed as much as possible from the oily globules, was similarly treated. 0·3506 gram of silver salt gave 0·2262 gram silver =64·5%, thus proving the principal acid to be acetic. The oily acid was present in too small a quantity for definite identification, and although it possessed a butyric-like odour, the silver salt showed it not to be that acid.

Determination of Sesquiterpene.—Fractions Nos. 6 and 7 (Table "B"), together with the residues from the various fractions of high ester No., totalling 100 c.c., were mixed together and treated at room temperature with alcoholic potash solution to decompose any remaining ester. The ester free oil (96 c.c.) was fractionally distilled at 10 mm. and the portion distilling below 136° C. at that pressure repeatedly distilled over metallic sodium at 10 mm. until free from oxygenated bodies. Finally about 32 c.c. of a colourless liquid, with a pleasant roselike odour, was obtained, possessing the following characters:—

Boiling point at 10 mm.	130 – 133° C.
Specific gravity 15/15° C.	0·9222
Optical rotation	+17·6°
Refractive index, 20° C.	1·5050

It did not yield any of the solid derivatives typical of sesquiterpenes, but gave the usual colour reactions with bromine vapour in acetic acid solution and sulphuric acid in acetic anhydride characteristic of such bodies as met with in essential oils of the Myrtaceæ. This sesquiterpene appears to be identical with that isolated by the writer from various Leptospermum oils, which for the present is assumed to be identical with eudesmene.

Determination of Sesquiterpene Alcohol.—The fractions of crude oil distilling above 136° C. at 10 mm. were redistilled until finally a distillate was obtained boiling at 134 – 138° C. at 5 mm. possessing the following characters:—

Specific gravity 15/15° C.	0·9443
Optical rotation	+7·6°
Refractive index, 20° C.	1·4961

It failed to react with phthalic anhydride when heated on the water bath in benzene solution. On heating, however, with an equal volume of 90% formic acid a sesquiterpene was obtained, but not in sufficient quantity for a thorough purification. The small quantity available possessed the following characters:—

Boiling point at 10 mm.	129 – 133° C.
Specific gravity 15/15° C.	0·9090
Optical rotation	–21·5°
Refractive index, 20° C.	1·5022

It did not yield any of the usual sesquiterpene derivatives, except the colour reactions referred to under "Determination of Sesquiterpene." This behaviour, however, was sufficient to show that the sesquiterpene alcohol was most probably that corresponding to the sesquiterpene occurring as such in the crude oil.

Determination of Stearoptene (probably a phenol ether). The high boiling residues, *i.e.*, those left behind after the separation of the sesquiterpene alcohol, solidified on cooling. After being spread on a porous tile the solid was collected, boiled up with ethyl alcohol, when upon cooling primrose yellow needles separated out. These melted at 103 – 104° C., and were found to contain one methoxyl group. The molecular formula deduced from combustion results and molecular determinations appears to be $C_{13}H_{18}O_4$.[1]

Other minor constituents.—In the course of the examination of the terpenes small quantities of bodies with pronounced odours were detected in the portions distilling a little lower than *d*-α-pinene, but were not present in sufficient quantity for their identity to be confirmed. They were isovaleric aldehyde and amyl alcohol.

In conclusion, I have to express my thanks to Mr. F. R. Morrison, A.T.C., Assistant Chemist, for his usual helpful assistance in these investigations.

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[1] See paper "Preliminary note on a new stearoptene (probably a phenol ether) occurring in some essential oils of the Myrtaceæ, by A. R. Penfold, F.C.S. and F. R. Morrison, A.T C., this Journal, Vol. LVI, 1922, pp. 87 – 89.

THE DISTRIBUTION OF THE ACTIVE DEPOSIT OF RADIUM IN HELIUM AND ARGON IN AN ELECTRIC FIELD.

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[*Read before the Royal Society of N. S. Wales, November 7, 1923.*]

Introduction.

In a previous paper[1] the writer investigated the distribution of the active deposit of radium and thorium in electric fields in various gases and confirmed the conclusion of Wellish[2] that in air and carbon dioxide there is a definite limiting percentage of the active deposit of radium initially positively charged, and that the remainder is neutral. The term "initial" refers to the state existing at the instant when the deposit atom has reached the end of its recoil path. The writer extended the work and found values for the percentage of RaA, RaB, ThA and ThB recoil atoms initially positively charged in the following gases:—air, carbon dioxide, nitrous oxide, methane, acetylene, ammonia, ethylene and hydrogen sulphide. The values for RaB were measured directly and values for RaA were calculated from the results for RaB and the values of $\frac{c-d}{c+d}$ where c and d are the activities found on the cathode and anode in a parallel plate exposure vessel when radium emanation is mixed with the gas under investigation and equilibrium is established between the emanation and its products RaA, RaB and RaC. The values found decreased in the order in which the gases are enumerated and it was pointed out that the stability of the gases for increase of temperature decreases in approximately the same order. A theory was given to explain the results based on the assumptions that the recoil atoms in their recoil path through the gas, dissociate the gas molecules, that at a collision at which dissociation does not occur the recoil particle has a large chance of becoming positively charged, and that at a collision at which dissociation does occur there is a large chance of this charge being lost. It was of interest, therefore, to extend the work to monatomic gases. This has been done in the case of helium and argon.

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[1] Phil. Mag., xli, p. 367, 1921. [2] Phil. Mag., xxviii, p. 417, 1914.

Experiments in Helium.

Helium was purified by circulation at atmospheric pressure for several hours round a closed path containing the exposure vessel, drying tubes and charcoal in liquid air. The purity of the gas was examined by the method described by Lord Rayleigh,[1] in which the alternative spark gap in air is measured for two electrodes in the gas. These electrodes were 5 cm. apart. When the alternative spark gap fell to a minimum which was about 0·6 to 2 millimeters, the pressure was adjusted to the required value, the taps leading in and out of the exposure vessel were closed and the active deposit allowed to accumulate on the electrodes. Radium emanation was supplied by a small quantity of radium in the vessel.

Preliminary experiments in the parallel plate exposure vessel described in the previous paper showed that about 5 per cent. of the active deposit was not positively charged. Experiments were then made in cylindrical vessels to test for negative particles using the method described by Wellish. The vessels were 10 cm. long and 4·6 cm. internal diameter with a central electrode 1·7 mm. in diameter. The activity on the rod when positive was found to be 0·003 of the total. This activity would be caused by neutral particles present to the extent of 3 per cent. It may be concluded therefore, that in helium as in all other gases investigated, negative particles are not present in sufficient numbers to be detected. In helium their presence to the extent of 1 in 1000 could easily have been detected.

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[1] Proc. Roy. Soc., Sept. 1920.

The method which was described in the former paper for measuring the percentage of RaB initially positively charged in a gas is not sufficiently accurate when the values are in the neighbourhood of 100 per cent. Hence only the value $\frac{c-d}{c+d}$, where c and d are the cathode and anode deposits after a long exposure to the gas mixed with radium emanation in the parallel plate vessel described in the previous paper, has been directly determined.

The effect of direct recoil to the electrode.

The effect of recoil on to the walls of the exposure vessel was negligible in the gases previously examined. However, in helium the activity reaching the anode by direct recoil from the gas is comparable with that due to the diffusion of neutral particles. It was found that the effect of direct recoil was best eliminated by making exposures at various pressures and plotting the observed values against the reciprocals of the pressures. The point 96·4 where the curve cuts the vertical axis in Fig. 1 is then the corrected value when the effect of direct recoil is eliminated, for the pressure corresponding to this point is infinite and the range of recoil zero. The experimental values found are as follows:—

$\frac{c-d}{c+d} \times 100$	Pressure in cm. of mercury.
76·2	3·92
79·4	5·00
80·8	5·72
83·9	7·75
83·9	7·86
92·2	23·0
94·7	40·7
95·0	80·0

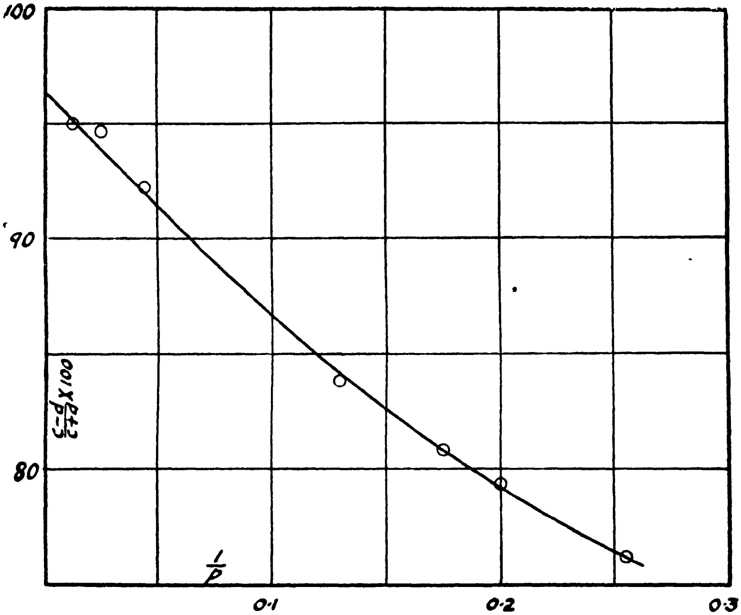

Fig. 1.

At the highest pressure the value did not alter when the potential between the plates was changed from 400 to 5000 volts. It is concluded therefore that $\frac{c-d}{c+d}$ is 0·964 for helium in the vessel used. This value represents the fraction of the active deposit apparently initially positively charged for an exposure in which radio-active equilibrium is established between the emanation and the products RaA, B and C, no account being taken of the fact that the value actually depends on the percentage of RaA and RaB positively charged and on the efficiency of recoil of RaB from the plates. This efficiency, for the brass plates cleaned with fine emery paper, was previously found to be 0·878.

Calculation of the percentages RaA and RaB initially positively charged in Helium.

Let

a = the fraction of RaA atoms initially positively charged,

b = the fraction of RaB atoms initially positively charged,
r = the efficiency of recoil of RaB from the plates,
$p = \frac{c-d}{c+d}$.

It was shown in the former paper that

$$a = \frac{2p-br}{2-br} \dots\dots\dots\dots\dots\dots (1)$$

and values of p, a and b are there given for eight gases. In each case it was found that b is greater than p and p greater than a. The value of a for helium may be determined in the following manner. From equation (1) when $b = 0$, $a = 0{\cdot}964$, and when $b = 1$, $a = 0{\cdot}936$. Hence a lies between these two values. If $b = 0{\cdot}964$, then $a = 0{\cdot}939$. So that unless helium is an exception to the rule noted above, the value of a lies between 0·936 and 0·939 and b lies between 0·964 and unity. It is of interest to compare these values with the results for other gases. The highest values previously found for RaA and RaB were those for air, namely 82·4% and 93% respectively, but there was evidence that the values for oxygen were slightly greater. The lowest values were found in hydrogen sulphide, zero and 54·9% respectively.

Experiments in Argon.

Argon was purified by sparking with oxygen for several weeks. The mean value found for $\frac{c-d}{c+d}$ was 75·5 per cent. Here also the value was independent of the voltage from 400 to 8000 volts. The test for negative particles showed that these were not present in sufficient numbers to be detected.

The percentage of RaB initially positively charged was measured by the method described in the former paper. It was found that the ratio of the percentage of RaB initially positively charged to the corresponding percentage for air was 0·88. It was previously found that 93 per cent. of RaB particles are initially positively charged in air. Hence the percentage for argon is 81·8. From this result and the value for p, it is readily deduced that the percentage of RaB initially positively charged in argon is 61·8.

Discussion.

This investigation shows that the theory very briefly outlined above, which has been given to explain the results published in the first paper is insufficient to account for all the facts, since neutral particles have been found to he present in the monatomic gases examined. Two new possibilities are now suggested which may result in the presence of neutral particles: (1) that at a collision, if the mutual penetration or the closeness of approach of the deposit atom and the gas molecule is sufficient, the deposit atom may lose its charge, whether dissociation of the molecule occurs or not; (2) if Wertenstein's conclusion, that recoil atoms are uncharged immediately after the expulsion of the alpha particle, is correct, it may happen that some of the recoil atoms do not become positively charged at any time during their recoil path. In either case the effect should be more pronounced in gases of high molecular weight. The penetration or closeness of approach may be expected to be greater with these gases and also fewer collisions are made before the translational energy of the recoil atom is reduced to that corresponding to the gas temperature. In argon only two head-on elastic collisions are required to halve the velocity of the recoil atom. Hence, the chance of the recoil atom acquiring a positive charge in argon, if initially unchanged, may be considerably smaller than in helium.

If either suggestion is correct we have a possible explanation of the relatively large number of neutral recoil atoms in argon, and of the small though finite number present in helium.

However, on the evidence available it appears that the dissociation of the gas by the recoil atoms may play a very important role, particularly in the more easily dissociated gases, and there seems to be no reason to modify the theory originally given in so far as it applies to the operation of this factor.

I wish to record my appreciation of the interest taken in the work by the late Professor Pollock, and by Professor O. U. Vonwiller, and also to thank Messrs. J. R. Duggan, R. J. Gillings, and S. L. Martin, who gave valuable help in the measurement of the percentage of RaB positively charged in argon.

The expense of this research was largely defrayed by a grant from the McCaughey Research Fund.

NOTES ON THE BACTERIOLOGY, TITRATABLE ACIDITY AND H-ION CONCENTRATION OF SOME CREAMS.

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[*Read before the Royal Society of N. S. Wales, November 7, 1923.*]

DURING recent years a considerable amount of attention has been devoted to the determination of the relationship between agar plate and microscopic counts of milk. In this paper an attempt has been made to obtain some similar data in the case of cream. At the same time determinations of the titratable acidity and hydrogen-ion concentrations were made with the object of obtaining some comparative figures, and also of noting if there were any correlation between bacterial counts, titratable acidity, H-ion concentration and cream grade.

Methods Employed.

Sampling.—Cream samples, taken with the necessary precautions, were obtained from College sources and from outside suppliers to the College butter factory; these samples consisted of fifty raw and seven pasteurised creams. They were taken during the five months commencing February (late Summer) and concluding in June (early Winter). The first raw sample taken was numbered one and the last, in June, fifty; pasteurised creams were numbered separately,

Agar Plate Cultures.—In making dilutions for these cultures each flask or tube was shaken for five minutes in an endeavour to obtain a breaking up of the bigger bacterial groups and to secure regularity of distribution of the bacteria in the diluent. The work of G. S. Wilson(1) indicates that a good quality tap water is a satisfactory diluent for the conditions, and Ringer's solution was not employed. Dilutions were arranged with a view of obtaining between thirty and four hundred colonies on each plate as recommended by R. S. Breed and W. D. Dotterrer(2) for milk analyses. Cultures were made in triplicate. It was realised that to obtain a great degree of accuracy, many more plates should be made from each sample. H. L. Reitz and H. A. Harding(3) state "that the results of approximately twenty-five simultaneous plate determinations should be averaged to give results which are satisfactorily accurate." The number of simultaneous plates actually used in this experiment, while not excluding the possibilities of inaccuracy in individual creams, should, over a large number of creams, give results from which deductions may justifiably be drawn. The maximum variation permitted in recorded plates was fifteen per cent.

The medium employed was a nutrient agar made from beef steak containing 1% Baker's peptone, 0·5% common salt, 1·5% thread agar, and adjusted to a H-ion concentration of pH = 7·0 by means of the colorimetric method described by Leon S. Medalia.(4) Sterilisation was effected by autoclaving at 15lbs. pressure for fifteen minutes. Incubation was for three days at room temperature, which, towards the end of the series (Winter), was raised somewhat by the use of a radiator. In counting plates, colonies were divided into two groups, those of the *Streptococcus lactis* type (alluded to as "pinpoint"), and others.

Microscopic Examination.—The method employed was essentially that of J. D. Brew and R. S. Breed(5) and was as follows:—1/100 of a c.c. of cream was taken by means of a calibrated capillary pipette and deposited on a 50 ×

114 mm. glass slide which was attached by rubber bands to a guide plate marked into areas of one square centimetre. Cream samples were evenly spread over such areas by means of a stiff platinum wire. Smears were dried on a level surface in a warm place protected from dust, flies, etc. The dried smears were immersed in xylol for two minutes, this time being found sufficient to dissolve out the butter fat. The smears were drained and dried and then immersed in 80% alcohol for two minutes. The slide was next flooded with an aqueous solution of methylene blue for a period of one minute, re-staining when necessary.

A zinc-free methylene blue, as recommended by H. J. Conn,(6) was not available until the latter half of the experiment. Pipettes were cleaned in chromic acid. The microscope, a Bausch and Lomb OCS 8, fitted with a 1·9 mm. oil immersion objective, a 6·4 eyepiece, eyepiece micrometer disc (having an 8 mm. circle) was standardised to give a field of 1/6000 c.m.; the tube length found necessary was 177 mm. In fields containing high numbers of bacteria ten quarter fields were counted; careful searching was done to ensure that these were fairly representative of the smear. More fields could have been counted with advantage, but the time thus involved was not available. The factor for the aggregate of the quarter field counts was thus 240,000 $\left(\frac{1}{100} \times \frac{1}{6000} \times \frac{1}{4} \times \frac{10}{1}\right)$. In those cases where there were few bacteria per field, one hundred full fields were counted and the factor adjusted accordingly to 6,000. The microorganisms present in a field were recorded in bacterial groups of less than four, four to nineteen, twenty to forty-nine, and more than forty-nine; yeast-like cells were recorded separately but included in the total count.

The relatively small amount of casein and albumen and the large proportion of butter-fat found in cream as compared with milk, may strengthen the criticism which has been urged against the method that the dissolving out of the fat may remove some bacteria by mechanical means; in some creams the butter-fat formed more than half (58%) of the cream. Brew and Breed(5) have stated that it is impossible to demonstrate that bacteria are removed mechanically in this way and that plate comparisons show that this loss, if any, is negligible.

Titratable Acidity.—These determinations were made immediately before the making of the colorimetric tests for pH, smears and petri dish cultures. The ordinary factory method was used of pipetting 8·8 c.cs. of cream into an enamel dish, adding two or three drops of phenolphthalein solution and titrating against decinormal sodium hydrate. The result was expressed in terms of lactic acid. The method has its obvious weaknesses, but it was desired to correlate, if possible, some other determinations with acidities as ordinarily obtained under factory conditions.

Hydrogen-ion Concentration.—The colorimetric method suggested by Leon S. Medalia(4) was followed. "If highly coloured fluids are to be titrated they may be diluted with equal parts or more of distilled water, since the addition of distilled water does not change the H.I.C. materially." In his method for the titration of culture media he recommends the dilution of the medium five times, and this degree of dilution was employed with creams and a powerful source of light used for illuminating the comparator block. Two cubic centimetres of cream were pipetted into each of three test tubes belonging to a series selected for uniformity of colour, thickness of wall, and diameter. Eight cubic centimetres of conductivity water (obtained by passing air free from ammonia and carbon dioxide through distilled water for twenty-four hours) were added to each and all thoroughly shaken. They were then placed in a comparator block and to the centre one 0·8 c.c. of the watery solution of the appropriate indicator added and all shaken again. Test tube pairs of the indicator solutions prepared according to Medalia, were placed behind the outer tubes and two tubes of distilled water behind the centre one. The test tube pairs of indicator solutions were changed until the centre tube was matched or was intermediate in colour.

The only indicators found necessary were:—

Indicator	Common Name	Range of -log (H) or pH =
O-carboxy benzene-azo-dimethyl aniline	Methyl Red	4·4 – 6·0
Di-bromo-o-cresol sulphone phthalein	Brom cresol purple	5·2 – 6·8
Di-bromo-thymol-sulphone phthalein	Brom thymol blue	6·0 – 7·6

Medalia's method seemingly lends itself rather to comparative results than to exact determinations of the H-ion concentration of the undiluted creams. It does not seem possible to calculate the H-ion concentration for the undiluted cream and all the figures given under the heading of pH in the following pages are those obtained with *five times diluted cream.*

Cream Grading.—Cream scoring forty-three points and above has been graded 'Choicest,' forty to forty-two 'First,' thirty-six to thirty-nine 'Second,' and below thirty-six 'Third Grade.' Grading was done by the College Instructor and Assistant Instructor in Dairying and one of us (V. Weston).

Results Obtained,

Counts of Micro-organisms.—A table is presented below showing in detail the results obtained from the agar cultures and the microscopic examination of the fifty raw creams, as well as their titratable acidities and H-ion concentrations. The creams are arranged in order of ascending titratable acidity. In the case of some creams the details are not complete. Counts of yeast-like cells are included in the total microscopic counts, and details of the number of these cells are tabulated below the table; their occurrence in a count is indicated by a letter in the total column.

Microscopic Counts.—The table shows that the highest total microscopic counts obtained were almost 1200 millions per c.c., and that four counts exceeding 1000 millions were obtained at an acidity of ·385% and upwards. Counts exceeding 1000 million individual bacteria in groups of less than four were obtained in only two instances, the lower acidity being ·45%. It is of interest to note that microscopic counts in the vicinity of 500 millions per c.c. were obtained from creams of an acidity as low as ·12% and ·125%. All creams (forty-three) of an acidity above ·11% had a count in excess of 100 millions per c.c. Generally speaking the groups of fifty or more in the microscopic examination occur irregularly up to an acidity of ·465%; above this percentage fewer creams contain bacteria in this group, though the cream with the highest titratable acidity possessed a remarkable number. The highest number of bacteria (241·68 millions) per c.c. in this grouping of fifty or more was in a cream of ·37% acidity. The highest numbers of bacteria (over 300 millions per c.c.) in the group containing four to nineteen individuals were in creams of ·26% and ·12% acidity; the cream of ·26% acidity also contained the highest number per c.c. in the twenty to forty-nine group, the count being almost 400 millions per c.c. This cream was characterised by the presence of an extraordinary preponderance of long-chain *Streptococci*—which apparently found the plate culture conditions (low incubation temperature) unsuitable for their growth since they do not appear in the agar plate count. R. S. Breed and J. D. Brew(7) found that 2·91% of 11,851 cans of milk graded by the microscopic method showed a predominant long chained streptococcus.

Table showing a comparison of the average plate and microscopic

Cream Sample				Colonies on Nutrient Agar pH = 7·0 expressed in millions per c.c.			
Number	Source	Titratable acidity expressed as lactic acid %	pH*	Pin-point colonies of *Streptococcus lactis* type	All other colonies	Total colonies	Percentage of total formed by other than 'pin-point' colonies
26	H.A.C.	·08	6·8	...	...	...	...
41	"	·09	7·0	...	...	...	...
38	"	·10	6·7	0·4	0·13	0·53	24·5
46	"	·10	6·8	...	...	...	...
35	"	·10	6·8	36·0	19·30	55·30	34·9
27	"	·11	6·5	32·0	8·26	40·26	20·5
45	"	·11	6·8	1·3	2·90	4·20	69·0
15	"	·12	6·6	34·0	2·80	36·80	7·6
30	"	·12	6·5	88·0	4·53	92·53	4·9
2	"	·125	...	...	...	...	...
16	"	·13	6·6	42·0	4·30	46·30	9·3
22	"	·135	6·5	70·0	9·80	79·80	12·3
1	Dell	·24	...	...	...	...	...
39	H.A.C.	·24	6·6	17·4	41·00	58·40	70·2
31	"	·26	6·5	154·0	9·00†	163·00†	5·5
28	"	·275	5·7	206·0	1·93	207·93	0·9
12	mixed	·28	5·8	25·0	0·80	25·80	3·1
8	H.A.C.	·31	6·0	156·0	10·80	166·80	6·5
14	Sellers	·32	5·7	84·0	1·00	85·00	1·2
50	H.A.C.	·32	6·5	186·0	150·00	336·00	44·6
40	Walden	·33	5·4	343·0	93·50	436·50	21·4
32	Welch	·34	5·6	210·0	7·00	217·00	3·2
37	Duffy	·36	5·3	328·0	56·00	384·00	14·6
19	Sellers	·37	5·5	270·0	5·30	275·30	1·9
4	H.A.C.	·37	...	259·2	0·85	260·05	0·3
49	Walden	·38	4·9	192·7	240·00	432·70	55·5
5	Welch	·385		239·6	0·77	240·37	0·3
48	Duffy	·40	5·5	270·0	288·00	558·00	51·6
24	"	·41	5·2	480·0	41·00	521·00	7·9
34	"	·41	5·2	140·0	29·30	169·30	17·3
36	Welch	·42	5·2	304·0	36·00	340·00	10·6
6	Sellers	·42	...	333·4	0·28	333·68	0·1
18	Welch	·42	5·3	400·0	12·30	412·30	3·0
21	H,A.C.	·425	5·4	570·0	64·00	634·00	10·1
10	"	·45	5·4	168·0	2·20	170·20	1·3
17	Dell	·45	5·5	380·0	94·00	474·00	19·8
20	Duffy	·465	5·2	502·0	4·00	506·00	0·8
9	H.A.C.	·47	5·4	92·0	1·10	93·10	1·2
29	McMahon	·475	5·3	320·0	100·00	420·00	23·8
44	Walden	·48	5·0	144·0	242·66	386·66	62·8
47	Welch	·48	4·8	180·0	270·00	450·00	60·0
25	McMahon	·495	5·4	...	...	...	...
42	Welch	·51	5·0	542·2	37·80	580·00	6·5
3	H.A.C.	·51	...	624·0	1·70	625·70	0·3
11	mixed	·51	5·4	162·5	1·10	163·60	0·7
23	Welch	·54	5·4	380·0	56·00	436·00	12·8
33	Sellers	·54	5·2	393·3	38·60	431·90	8·9
43	Duffy	·54	5·2	132·0	328·00	460·00	71·3
7	Dell	·56	5·5	248·7	12·80	261·50	4·9
13	Welch	·61	5·6	384·0	13·20	397·20	3·3

* pH of diluted cream; see notes under " Methods employed."

† Large number of long-chained *Streptococci* shown in the microscopic

a. Included in the total count are 0·48 million yeast-like cells.
b. " " " 0·24 " "
c. " " " 0·48 " "
d. " " " 0·24 " "

counts of creams whose titratable acidity lies between the limits given.

Brew and Breed Method.

Millions of micro-organisms contained, per c.c., in groups of:				Total count in millions per c.c.	Percentage of total count formed by groups of four or more
Less than four	Four to nineteen	Twenty to forty-nine	More than forty-nine		
8·52	6·30	12·78	0·00	27·60	69·1
...	...	...	...	...	...
...	...	...	...	...	...
4·87	0·00	0·00	0·00	4·87	0·0
97·92	48·48	14·40	0·00	160·80	29·1
48·00	50·40	58·80	0·00	157·20	69·5
3·42	0·00	0·00	0·00	3·42	0·0
141·60	80·00	89·04	16·80	327·44	56·8
75·36	312·72	94·56	38·88	521·52	85·5
217·36	65·73	122·74	92·91	498·74	56·4
142·56	81·60	33·84	0·00	258·00	44·7
169·68	125·76	88·80	33·60	417·84	59·4
484·31	156·94	93:86	25·27	760·38	36·3
128·64	19·44	17·76	0·00	165·84	22·4
162·00	318·72	395·52	78·00	954·24	83·0
521·28	35·04	28·56	0·00	584·88	10·9
436·56	35·28	5·04	0·00	477·36 a	8·4
291·12	67·20	121·92	97·44	577·68	49·6
406·56	51·60	4·80	0·00	463·20 b	12·2
353·04	64·08	43·68	12·00	472·80	25·3
623·04	89·76	33·84	0·00	746·64	16·5
498·48	33·13	7·20	22·08	561·37 c	11·2
436·08	19·44	22·08	0·00	477·60	8·7
505·20	121·68	0·00	0·00	626·88	19·4
294·12	142·69	215·27	241·68	893·76	67·1
686·40	98·88	62·88	0·00	848·16	19·1
750·88	173·37	107·54	0·00	1031·79	27·2
906·96	54·96	8·16	0·00	970·08	6·5
420·48	57·84	24·24	13·44	516·00	18·5
390·48	31·44	0·00	0·00	421·92	7·4
351·60	48·72	26·64	0·00	426·96	17·7
532·00	101·46	135·66	147·25	916·37	41·9
521·76	70·32	19·20	0·00	611·28	14·6
795·84	91·68	13·44	24·60	925·20 d	14·0
680·88	81·60	52·32	50·34	870·90 e	21·8
1060·32	86·40	22·08	24·00	1192·80	11·1
647·04	130·32	42·72	15·84	835·92	22·6
464·16	71·76	34·32	0·00	576·96 f	19·6
799·20	81·60	48·00	0·00	928·80	14·0
573·60	104·16	26·40	0·00	704·16	18·5
826·56	51·36	0·00	0·00	877·92	5·8
508·32	45·84	29·04	0·00	583·20	12·8
745·44	32·44	31·92	0·00	809·80	7·4
1025·05	89·87	83·22	0·00	1198·14	14 4
692·64	116·88	34·32	240·00	1083·84	36·1
702·48	88·32	8·88	16·80	816·48	14·0
549·60	97·68	13·44	0·00	660·72	16·8
766·56	54·96	23·52	0·00	845·04	9·3
599·28	71·76	62·64	13·20	746·88	19·8
716·64	36·00	20·88	84·00	986·40 g	27·4

examination of this sample apparently did not grow under the conditions.

e. Included in the total count are 5·76 million yeast-like cells.
f. ,, ,, ,, 6·72 ,, ,,
g. ,, ,, ,, 128·88 ,, ,, .

Agar Plate Counts.—The highest plate count obtained under the conditions was 634 millions per c.c. in a cream of ·425% acidity.

The variation in plate count is marked in cases. Thus at an acidity of ·10% creams produced at the same season contained half a million and fifty-five millions of bacteria per c.c. This is probably explained by the different ages of these creams, the cream with the lower count being taken direct from the separator.

At an acidity exceeding ·32% only one cream out of twenty-nine had a count of less than 100 millions per c.c. and the average count for these creams, which include the great majority of those from outside suppliers, was over 370 millions per c.c. of which over 295 millions represent colonies of the pin-point type. Further figures are given in the next section.

L. T. MacInnes and H. H. Randell(8) found the following counts in N.S. Wales creams having an acidity in excess of ·43%—108, 151 and 163 millions per c.c. Conn and Esten(9) give a count for cream forty-eight hours old (acidity not stated) of 1023 millions per c.c., the cream being held at between 20° and 21° C. and the medium lactose gelatin.

Comparison of the Microscopic and Agar Plate Counts.—"Bacteria frequently exist in milk in clumps of twos, threes, fours, or even larger masses. Since these clumps cannot be perfectly separated into their component individuals by any known method of shaking or manipulation, the culture medium is always seeded with many groups of bacteria. As these grow they form a single mass, or colony, indistinguishable from colonies which have arisen from single individuals."—Breed, R. S. and Stocking, W. A.(10) This factor, coupled with the inability of the whole of the bacteria to grow under any one set of conditions makes the plate count an imperfect method of determining the total number of individual bacteria in milk or cream. Actual microscopic examination of milk or cream smears, suitably stained, shows the individual bacteria present, though the method will suffer from the deficiencies of any staining process and may reveal dead cells. Concerning the matter of dead cells the following passage from J. M. Sherman and W. R. Albus$^{(11)}$ is of interest—"Since the younger bacteria, like the young of higher forms of life, are more susceptible to the hazards of their environment, it is not improbable that in the struggle for existence among the organisms there occurs a certain mortality among the young cells—an 'infant mortality' so to speak. If such exists, another factor must be considered in the discussion of the relative merits of the direct and cultural methods of bacterial enumeration." G. S. Wilson$^{(1)}$ presented figures to show that there is a mortality rate of about 10% in young cultures.

The marked increase of the total microscopic over the total plate count, and the somewhat irregular relation of the total counts to the titratable acidity is illustrated in Figure 1. The respective counts and ratios between them are discussed elsewhere.

*Correlations**—Correlation figures were found as follow:

48 Creams	Titratable acidity	and	"less than 4" microscopic count		·793 = ·036
	„	„	total „	„	·730 = ·046
44 Creams	„	„	total plate count ...	...	·702 = ·051
	„	„	"pin.point" plate count	...	·509 = ·075

The number of samples represented in the results on which the correlations are based is small. Nevertheless the correlation between the microscopic count and the titratable acidity is significant.

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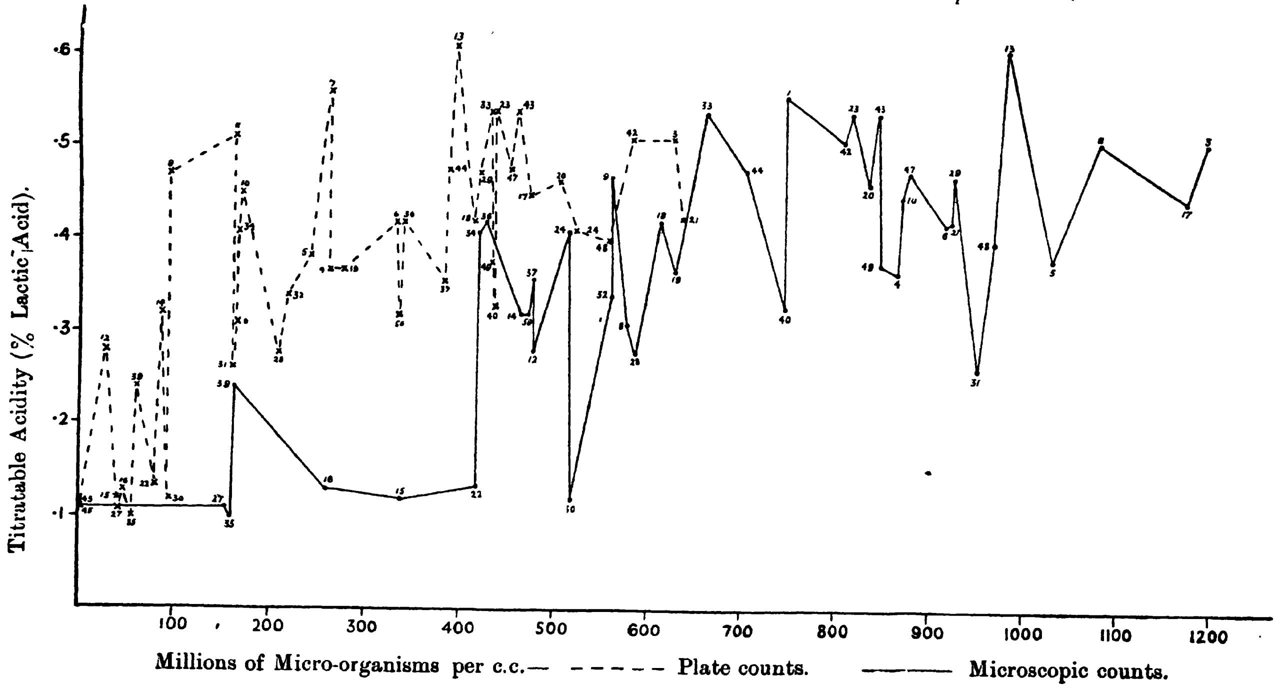
* Correlation figures were kindly worked out by the Principal of the College Mr. E. A. Southee, O.B.E., M.A.

Figure 1—*Showing Titratable Acidity, Total Plate and Total Microscopic Counts.*



The acidities of the creams in Table I fall somewhat naturally into five groups, and an arrangement of average microscopic and agar plate counts within these groups is given in Table II which follows:

Table II—*A comparison of the microscopic and plate counts for certain ranges of titratable acidity.*

Titratable acidity range, (acidity expressed as percentages of lactic acid).	Total count in millions per c.c.					
	Average		Maximum		Minimum	
	Microscopic method	Plate method	Microscopic method	Plate method	Microscopic method	Plate method
·08 – ·135	237·7	44·5	521·5	92·5	3·4	0·5
·24 – ·28	588·5	113·8	954·2	207·9	165·8	25·8
·31 – ·385	670·0	283·4	1031·8	436·5	463·2	85·0
·40 – ·495	757·2	390·6	1192·8	634·0	421·9	93·1
·51 – ·61	893·4	419·5	1198·1	625.7	660·7	163·6

Millions of micro-organisms per c.c.					
Average		Maximum		Minimum	
Individual bacteria present in groups of less than four (microscopic method	Pinpoint colonies (plate method)	Individual bacteria present in groups of less than four (microscopic method)	Pinpoint colonies (plate method)	Individual bacteria present in groups of less than four (microscopic method)	Pinpoint colonies (plate method)
90·9	38·0	217·4	88·0	3·4	0·4
346·6	100·6	521·3	206·0	128·6	17·4
484·5	226·8	750·9	343·0	291·1	84·0
631·9	305·9	1060·0	570·0	351·6	92·0
724·7	358·3	1025·0	624·0	599·3	132·0

An almost consistent increase is shown in bacterial numbers as one moves from a group of low to another of higher acidity. There is a tendency for the numbers to fall off when the acidity reaches the vicinity of ·5%; this is a relatively higher figure than in milk since the proportion of water and non-fatty solids in cream is so much lower. This falling off is less marked in the microscopic count than it is in the plate one. Such may be due to the staining and counting of dead cells in the microscopic method. The most notable increase in numbers occurs in the second acidity group, the first acidity group numbers being at least doubled in all but one case.

The contrast between the maximum and minimum number of bacteria in an acidity group is marked in both methods of estimating the bacteria present. In one case the estimated pinpoint colonies per c.c. associated with a cream of ·54% acidity are 132 millions, while the average estimate for these colonies in creams of ·24% to ·28% acidity is slightly over 100 millions. It is worthy of note that in the case of this cream, as will be seen from Table I, the total count is large, 460 millions by the plate method and 845 millions microscopically.

From a consideration of the number of bacteria (pinpoint colonies) which may be broadly taken as of the *Streptococcus lactis* type and the corresponding acidity, it is apparent that there is no definite *individual* relationship in creams between acidity and numbers of *Streptococcus lactis* cells. P. G. Heinemann(12) found "that the amount of acid formed during the souring process of the milk or cream is not solely dependent upon the number of bacteria present of the *Streptococcus lacticus* group. Temperature and the presence of other bacteria may influence the result."

Ratio of the Microscopic to the Agar Plate Count.—The ratios, calculated from Table I, are shown below:—

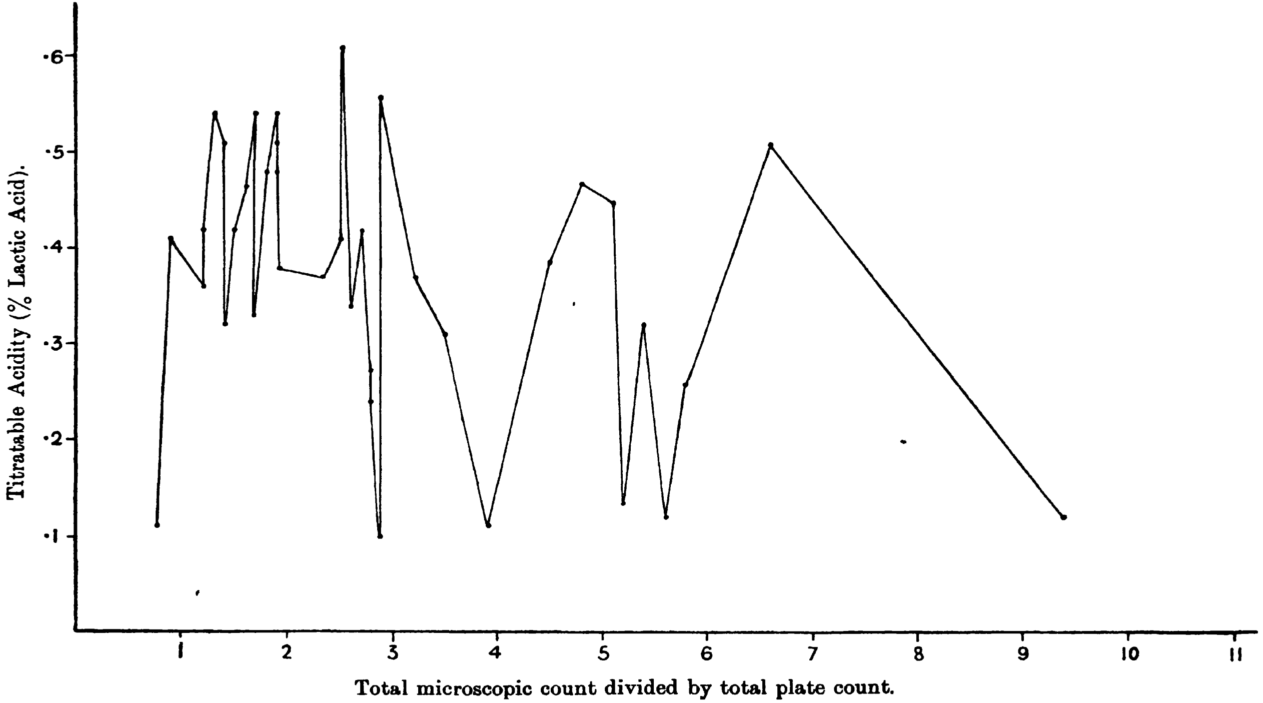
a. The ratio of the total microscopic to the total plate count	2·3 : 1
b. The ratio of the "less than four" groups in the microscopic count to the pinpoint colonies in the plate count	2·1 : 1
c. Ratio of the total agar plate count to the pinpoint colonies	1·25 : 1
d. Ratio of the total to the "less than four" groups in the microscopic count	1·34 : 1

a. *Ratio of the total microscopic to the total agar plate count.*—In the case of creams somewhat different results would be expected from those normal in milk owing to the much more advanced stage fermentation has reached—as indicated in the respective acidities. A. H. Robertson(13) gives the milk ratio of the total microscopic count to the plate count, when incubated for five days at 21° C., as 2·5 : 1. The corresponding ratio calculated from the whole of the creams in Table I is 2·3 : 1. The ratio varies very considerably at different titratable acidities as shown in figure 2.

Figure 2 shows that the ratios from 1 : 1 to 2 : 1 are grouped between acidities of ·32 and ·54%. If the creams between an acidity of ·08 and ·26% be grouped and the average ratio be obtained, it is found to be 5·1 : 1; the creams above ·26% acidity give a ratio of 2·1 : 1. These differences in ratio are to be expected owing to the predominance at the higher acidities of the *Streptococcus lactis* type which forms but short chains, while long chains and big clumps are common in creams of low acidity.

There is, however, an absence of bacteria in groups of more than four in the cases of the two creams of lowest microscopic count (less than five millions per c.c.). This experience is somewhat paralleled by some results of J. D. Brew and W. D. Dotterrer(14)—"Generally speaking, the 'groups' of bacteria appear to be of small average size in milk containing very few bacteria and to increase in average size as the number of bacteria increases, reaching a maximum average size of twelve to fourteen individuals in milk containing less than a million bacteria per c.c. As the number of bacteria becomes greater than this the average size of the groups diminishes. Apparently this decrease in the average size of the groups in milk contain-

Figure 2—*Showing Titratable Acidity and Corresponding Ratio of Total Microscopic to Total Plate Count in Individual Creams.* (Note—one ratio 18·6 : 1, acidity ·28% has been omitted).



ing large numbers of bacteria is due to the increasing predominance of the lactic bacteria."

In detail, with the creams arranged in the five acidity groups, the ratio of the microscopic to the plate count works out as follows:

Table III.

Acidity Group	Ratio of total microscopic count to total plate count	Ratio of groups of less than four (microscopic) to pin-point colonies in plate count
·08 - ·135	5·3 : 1	2·4 : 1
·24 - ·28	5·2 : 1	3·4 : 1
·31 - ·385	2·4 : 1	2·1 : 1
·40 - ·495	1·9 : 1	2·1 : 1
·51 - ·61	2·1 : 1	2·2 : 1

The frequency distribution of the ratios of the individual microscopic to the agar plate count is clearly indicated in Figure 3, prepared after the manner of A. H. Robertson⁽¹³⁾

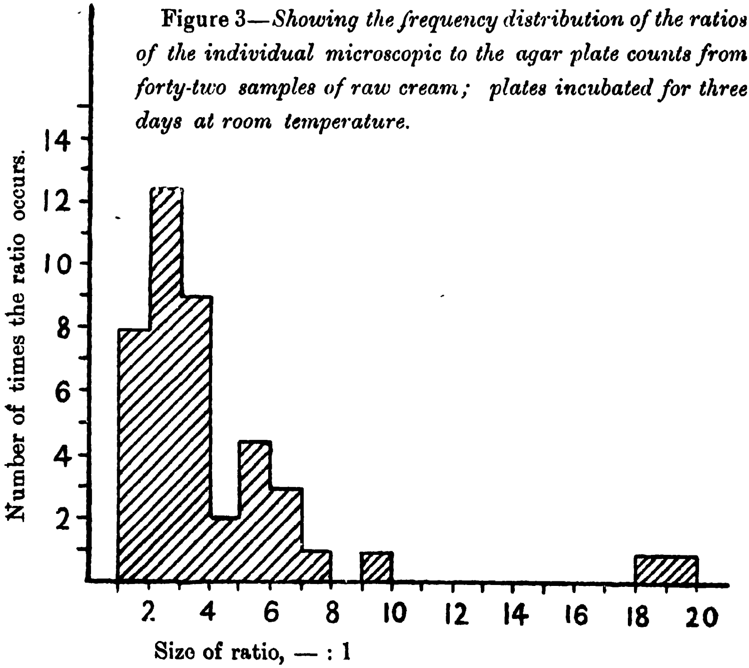


Figure 3—*Showing the frequency distribution of the ratios of the individual microscopic to the agar plate counts from forty-two samples of raw cream; plates incubated for three days at room temperature.*

The figure shows that the ratios of the total microscopic to the total agar count lie commonly between 1 : 1 and 3 : 1, the most frequent ratio being 2 : 1.

b. *Ratio of the microscopic groups of less than four to the pinpoint colonies growing on agar.*—In making the microscopic counts the groups of less than four were kept separate because it was thought that these groups might include the bulk of the *Streptococcus lactis* type of bacteria. In the majority of creams this was apparently so, few rods or cocci of other types being found. There were, however, two creams exceptional in nature. They were numbers 2 and 39 shown in Table I; both contained a considerable number of single rods—in cream No. 39 about one quarter of the less-than-four groups consisting of these bacteria.

The ratio of the microscopic groups of less-than-four to the agar pinpoint colonies for the whole of the creams was 2 : 1. The "acidity group" variations from this figure are shown in Table III. This figure is of interest in view of the fact that the *Streptococcus lactis* type of organism commonly occurs in the diplo form. J. C. Baker, J. D. Brew and H. J. Conn,(15) having inoculated a pasteurised skim milk low in bacteria with a culture of *Streptococcus lactis*, found the ratio of the individual microscopic to the plate count to be 1·8 : 1.

While pinpoint colonies were examined occasionally and proved to be typical of the common milk-souring organism, it is possible that some other than *Streptococcus lactis* colonies were included in the pinpoint colony count, particularly in view of the period of incubation.

c. *Ratio of the total agar count to the agar pinpoint colonies.*—This ratio averages 1·25 : 1. The counts on which the ratio is based are peculiar in that they do not show any marked increase in the percentage of pinpoint colonies at the higher acidities.

Table IV.—*Colonies on Nutrient Agar* pH = 7·0, *expressed in millions per c c. of cream.*

Limits of titratable acidity expressed as lactic acid	Pinpoint colonies of the *Streptococcus lactis* type	Total colonies	Percentage that pin point colonies form of total count
·08 – ·26%	47·5	57·7	82·3
·275 – ·61	283·8	349·8	81·1

There is, of course, a marked increase of both pinpoint and total colonies in the creams of higher acidity, but the proportion of pinpoint colonies does not materially alter in the two groups of creams. This is contrary to expectation and may be explained by the fact that the method of incubation did not favour the other-than-pinpoint colonies. That there is a marked percentage increase in the content of the *Streptococcus lactis* type of bacteria in the higher acid creams is evidenced by details of microscopic counts which follow.

d. ***Ratio of the total to the less than four groups in the microscopic count.***—In Table V it will be noted that the percentage of organisms in groups of less than four increases from thiry-four in the case of the lower acid creams to eighty in creams of the higher acidities.

Table-V.—*Bacterial counts by the Brew and Breed microscopic method; micro-organisms expressed in millions per c.c.*

Limits of titratable acidity expressed as lactic acid	Present in groups of less than four	Total count of all groups	Percentage formed of total count by groups of less than four micro-organisms
·08 – ·26%	129·6	327·5	39·5
·275 – ·61	602·3	750·5	80·3

Comparison of H-ion concentration and titratable acidity of individual creams.

As indicated, the determinations of H-ion concentration, expressed as pH, is for a diluted cream. The H-ion concentration and titratable acidity figures do not run parallel, a result which was to be expected from the well-known variation in the relative quantities of the organic acids present in cream fermentations.

Table VI.—*Corresponding Acidities expressed as lactic acid.*

pH*	Individual Creams	Average Acidity	Minimum Acidity	Maximum Acidity
4·8	·48,	...	...	...
4·9	·38,	...	...	...
5·0	·51, ·48,	·495	·48	·51
5·2	·54, ·54, ·465, ·42, ·41. ·41,	·46	·41	·54
5·3	·475, ·42, ·36,	·42	·36	·475
5·4	·54, ·51, ·495, ·47, ·45, ·425, ·33,	·46	·33	·54
5·5	·56, ·45, ·40, ·37,	·445	·37	·56
5·6	·61, ·34,	·475	·34	·61
5·7	·32, ·275,	·30	·275	·32
5·8	·28,	...	...	...
6·0	·31,	...	...	...
6·5	·32, ·26, ·12, ·11,	·20	·11	·32
6·6	·24, ·13, ·12,	·16	·12	·24
6·7	·10,	...	...	...
6·8	·10, ·08,	·09	·08	·10
7·0	·09,	...	...	...

* Cream five times diluted with conductivity water for measurements in this column, while numbers in other columns refer to undiluted creams.

With creams diluted as described, the pH has not exceeded 4·8 and the lowest H-ion concentration was pH = 7·0. If the acidity present were solely due to lactic acid, then a five times diluted cream of pH reading 5·4 would have an undiluted reading (calculated) of pH = 4·7. The relative amounts of individual organic acids present in cream vary with each fermentation and consequently preclude calculation of the undiluted hydrogen-ion concentration.

Creams with titratable acidities as different as ·34 and ·61% had the same pH. More remarkable, perhaps, is the fact that creams of ·11 and ·32% titratable acidity have the same pH; since at the lower acidity of ·11% (in a cream derived from a Jersey herd) the amount of free organic acids which have resulted from fermentation must be very low.

The highest titratable acidity was ·61%; the cream was second-grade, contained the highest number of yeast-like cells (128 millions per c.c.) found in any sample, and contained 38% butter-fat. The lowest figure was ·08 determined in a cream derived from College milk and taken direct from the separator.

A general relationship between pH readings and titratable acidity is shown in Figure 4. The average titratable acidities of creams whose pH readings are the same have been plotted. The average titratable acidity rises fairly regularly up to about ·4%, when the graph becomes irregular.

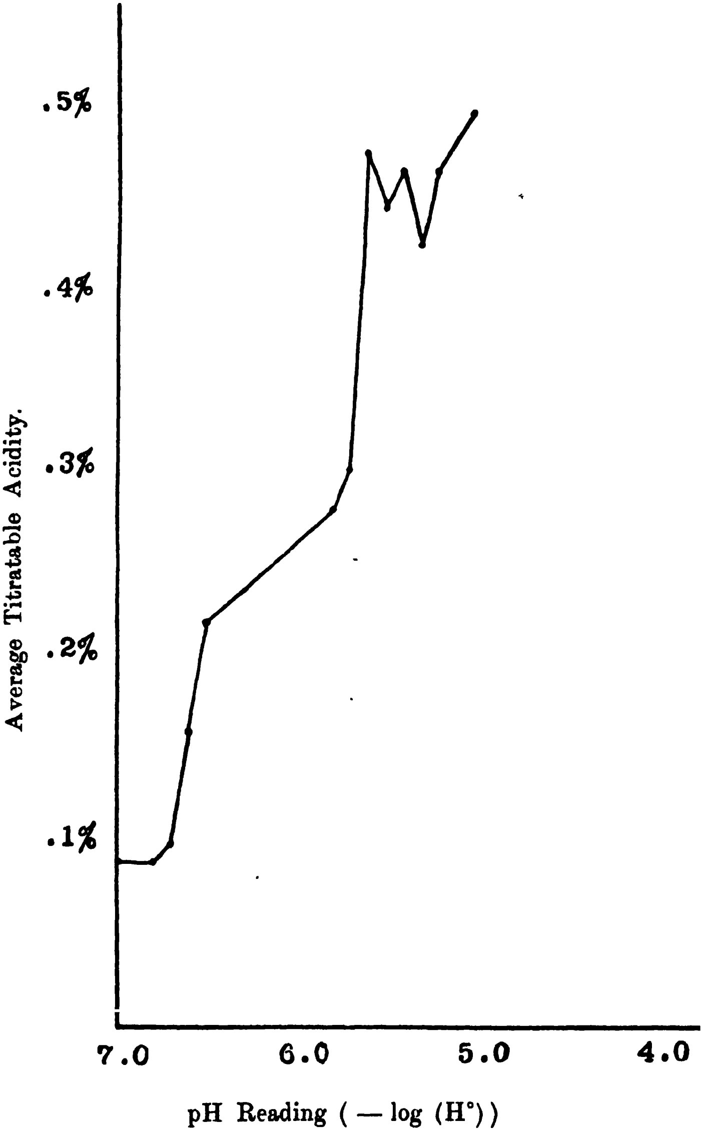
The considerable individual variation with creams of the same pH should not be lost sight of (Table VI).

Comparison of Cream Grades and Titratable Acidity.

Table VII.—*Table showing Cream Grades and Titratable Acidity expressed as Lactic Acid.*

Grade of Creams	Grade Mark of Creams	Determinations of titratable acidity expressed as percentage of lactic acid	Average titratable acidity per grade mark	Average titratable acidity within a grade
Choicest	43	·08, ·09, ·10 (2), ·11 (2), ·24, ·26, ·31, ·32, ·425, ·45	·22	·22
First	42	·12 (2), ·13, ·275, ·28, ·32, ·36, ·40, ·465, ·47 (2), ·48, ·495, ·51 (2), ·54	·37	·37
,,	41	·125, ·24, ·33, ·37, ·385. ·42	.31	
,,	40	·135, ·41, ·42, ·48, ·51, ·56	·42	
Second	39	·38, ·41, ·54	·44	·45
,,	38	·37, ·42, ·54, ·61	·48	
,,	37	·34	·34	
,,	36	·45	·45	

Figure 4.—*Showing the average titratable acidity of creams whose pH reading is the same.*



The table confirms the current opinion that there is no clearly defined relationship between acidity, as usually determined, and the quality grade of an individual cream. In particular instances, creams of as widely divergent acidities as ·08 and ·45% were of "Choicest" quality, and ·37 and ·61% of "Second" quality.

In general, as indicated in the average for each grade, choicest creams are those in which little acidity has been formed; the average acidity of lower grade creams is higher than those of a better grade.

In drawing conclusions from the figures it should be remembered that creams of high butter-fat percentage contain less of the other milk solids and of water than do those of lower butter-fat percentage. Consequently high butter-fat creams are poorer in the foodstuffs of the normally predominant cream bacteria. In addition, owing to the lower water content, creams high in butter-fat require a lesser formation of acid to reach the same acid concentration in cream serum.

Hydrogen Ion Concentration of Cream.—In Table I are given the Hydrogen-ion concentrations of the diluted cream samples, determinations being made by the method previously described.

Quite a number of factors influence the amounts of the proteins, and the proportions and composition of the mineral constituents present in cream, and these would have a marked effect on the H-ion concentration. Moreover, when it is remembered that the proportions of the various organic acids present in the cream vary with the types of micro-organisms predominating, or sharing in the fermentations, and that the dissociation constants of formic, acetic, butyric, lactic and other of these acids differ very considerably from each other, it is obvious that the pH of a cream is more closely related to the types of acids present and their respective amounts than to the titratable acidity. Determinations of the amounts of the various acids present were not made and, consequently, it has not been possible to determine the pH of the undiluted samples. Since measurement of the pH might be indicative of the type of fermentation occurring, it was thought that there might be a correlation between pH and cream grade. This is apparently not so with individual creams as shown in the table below, but the average pH within a cream grade is higher for higher quality creams.

Table VIII.—*Table showing Cream Grade and Hydrogen Ion Concentrations.*

Grade of Creams	Grade Mark of Creams; max.=50	pH* Determinations	Average pH* per Grade Mark	Average pH* within a grade
Choicest	43	7·0, 6·8 (3 samples), 6·7, 6·6, 6·5 (2), 6·0, 5·7, 5·4 (2)	6·4	6·4
First	42	6·6 (2), 6·5 (2), 5·8, 5·7, 5·5, 5·4 (3), 5·3 (2), 5·2 (2), 5·0, 4·8	5·6	5·6
,,	41	5·4, 5·2	5·3	
,,	40	6·5, 5·5, 5·2, 5·0	5·5	
Second	39	5·4, 5·2, 4·9	5·2	5·4
,,	38	5·6, 5·5, 5·3, 5·2	5·4	
,,	37	5·6	5·6	
,,	36	5·5	5·5	

* Determined from diluted cream; see notes concerning methods used.

"*Streptococcus lacticus* from milk was found" by O. Svanberg(16) "to have optimum growth between pH = 5·5 and pH = 6·4, and the growth rate decreased markedly when the acidity became lower." Referring to Table I, it will be seen that only one cream with a titratable acidity above ·26% has a H-ion concentration lower than 6·4; and it was shown on page 273 that the increase in the groups of less than four in the microscopic count was marked in creams having an acidity greater than that which corresponds, as indicated above, to a pH of 6·4. Moreover, the creams with an acidity in excess of pH = 6·4 have a ratio of the microscopic to the plate count of about 2 : 1 while those with an acidity less than that indicated by pH = 6·4 have a ratio of 5 : 1. These relations indicate the predominance of *Streptococcus lacticus* in the creams of higher H-ion concentration than pH = 6·4, presumably due to the increased absolute or comparative growth rate of this organism under such conditions of H-ion concentration, as found by Svanberg.

Pasteurised Creams.—The results from the pasteurised creams are presented in the table given below:

Table IX.—*Table showing particulars of determinations made with pasteurised creams.*

Sample	Titratable acidity expressed as lactic acid %	pH*	Cream grade marks	Agar plate count in millions per c c.		
				Pinpoint colonies	All other colonies	Total
101	·09	6·8	43	0·33	4·40	4·73
102	·11	6·8	"	1·70	26·90	28·60
103	·11	6·7	"	10·70	45·80	56·50
104	·12	6·8	"	1·87	5·93	7·80
105	·13	6·7	"	1·67	25·80	27·47
106	·13	6·7	"	3·70	24·30	28·00
107	·14	6·8	"	4·33	50·27	54·60

* Cream five times diluted with conductivity water.

Counts of Micro-organisms.—The cream was obtained from a market milk depôt, which separated its excess pasteurised milk.

Microscopic Count.—From the work of E. G. Hastings and A. Davenport(17) it seems certain that the use of the direct microscopic count for pasteurised cream would not give reliable results. With reference to milk it is stated that "In the sixteen series of market milk counts tabulated, the post-pasteurisation counts vary from eighteen per cent. to eighty-three per cent. of the corresponding raw milk counts." Microscopic counts of the creams were not made.

Agar Plate Count.—The pinpoint colonies formed 11·7% of the total count. For creams from fresh milk some of the counts are high and indicate faulty pasteurisation or post-pasteurisation conditions.

Titratable acidity, H-ion concentration and cream grade.—Considering the creams as a group the H-ion concentration is lower for corresponding titratable acidities than the concentration at similar acidities in the case of raw creams. The number of pasteurised creams from which this conclusion is drawn are, however, few.

All the pasteurised creams were of "Choicest" grade while five out of the eleven graded raw creams with titratable acidities below ·14% (these acidities averaging slightly less than the pasteurised creams) were a cream grade lower, averaging 41 2/5 grade points.

The writers of this paper wish to express their appreciation of the assistance given by Professor C. E. Fawsitt and Mr. Gilbert Wright, of the University of Sydney, and Messrs. Benjamin, MacGillivray, Dart and Scott of the Hawkesbury Agricultural College.

Summary.

(1) A comparison has been made of the individual microscopic count and the agar plate count of forty-two samples of raw cream. In making the individual microscopic count separate details were kept of the bacteria occurring in groups of less than four, four to nineteen, twenty to forty-nine and fifty or more; yeast-like cells were counted separately but included in the total microscopic count. In plate counts pinpoint colonies of the *Streptococcus lactis* type were recorded separately from other colonies. Determinations of H-ion concentration (made according to a method suggested by Leon S. Medalia)(4) have been compared with the titratable acidities and cream "grades."

(2) The average individual microscopic count of the raw creams was 636 millions per c.c., and the average for the agar plate counts 283 millions per c.c. The highest individual microscopic count was 1198 millions per c.c. and the lowest 3·4 millions; the highest plate count, 634 millions per c.c., and the lowest 0·5 millions per c.c.

(3) The average ratio of the individual microscopic to the agar plate count was 2·3 : 1. With creams of acidity lying between the limits of ·08 — ·26% (expressed as lactic acid) the ratio was 5·7 : 1, and with creams of above an acidity of ·26% the ratio was 2·1 : 1. The ratio of the less than four groups in the microscopic count to the pinpoint colonies of the agar count was 2 : 1. Agar plates were incubated for three days at room temperature in a district whose mean annual temperature is 63·3° F. (17·4° C.)

(4) Considerable differences of titratable acidity were found for a given H-ion concentration. The lowest H-ion concentration found in a five times diluted cream and expressed as pH was pH = 7·0 and the highest pH = 4·8.

(5) No individual relationship of cream "grade" and H-ion concentration was found.

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ACACIA SEEDLINGS, PART IX.

By R. H. CAMBAGE, F.L.S.

[With Plates XVI - XIX.]

[Read before the Royal Society of N.S. Wales, December 5, 1923.]

SYNOPSIS:

VITALITY OF SEEDS IN SEA-WATER.
SEQUENCE IN THE DEVELOPMENT OF LEAVES.
PERIOD BETWEEN FLOWER BUDS AND FLOWERS.
NUMBER OF PINNÆ ON ONE LEAF.
DESCRIPTION OF SEEDLINGS.

Vitality of Seeds in Sea-Water.

A seed of *Acacia penninervis* var. *falciformis* from Jenolan Caves germinated when placed in boiling water and planted after having been immersed in sea-water for six years. This probably constitutes a record for this experiment.

I have previously recorded a seed of *A. melanoxylon* having germinated after five years in sea-water (Part VIII, p. 130), and a seed of *A. Farnesiana* after three and three quarter years (Part IV, p. 410), and now record a seed of *A. podalyriæfolia* having germinated after having been four years in sea-water.

Sequence in the Development of Leaves.

In Part VIII (p. 130), it was mentioned that 104 species of Acacia had been found to commence in nearly every case with one simply pinnate leaf, while 17 had an opposite pair. The following eight may be added to the former list, which brings the total to 112:—*A. anceps* DC., *A. Burrowi* Maiden, *A. humifusa* A. Cunn., *A. horrida* Willd. (Africa), *A. pseudeburnea* (India), *A. sericata* A. Cunn., *A. siculiformis* A. Cunn., *A. viscosa* Schrad.

To the 17 species commonly having an opposite pair of simply pinnate leaves the following four may be added:—*A. Gilberti* Meissn., *A. leptopetala* Benth., *A. pentadenia* Lindl., *A. pulchella* R. Br., making the total 21.

Period between Flower-Buds and Flowers.

Observations were made to ascertain the period between the time the flower-buds appear and when the plant is flowering. From the following list it may be seen that in some species the period is as much as nine months. These periods may fluctuate to the extent of a few weeks in different individuals under varying conditions.

Acacia Species.	Date of Flower-buds.	Date of Flowering.
accola	November	July and August
asparagoides	do.	June and July
aspera	do.	August
Baileyana	do.	July
pycnantha	do.	August
cardiophylla	December	August
cultriformis	do.	September
crassiuscula	do.	August
decora	do.	August
diffusa	do.	June and July
elongata	do.	August
flexifolia...	do.	July and August
neriifolia	do.	August and September
rigens	do.	June and July
rubida	do.	August
polybotrya	do.	August
spectabilis	do.	July and August
amblygona	January	June and July
decurrens var. *normalis*	do.	August
doratoxylon	do.	September
lineata	do.	August
podalyriæfolia	do.	June
conferta...	February	April
homalophylla	April	September

Number of Pinnæ on One Leaf.

In addition to those phyllodineous Acacias already recorded as having more than one pair of pinnæ on one leaf (Part VIII, p. 131), *A. melanoxylon* may have ten pairs.

Description of Seedlings.

PUNGENTES—(Uninerves).

ACACIA SICULIFORMIS A. Cunn. Seeds from Eaglehawk Neck, Tasmania (Miss M. F. Cambage). (Plate XVI, Numbers 1 to 3).

Seeds brownish-black, oblong to oblong-oval, 3 to 4 mm. long, 2 to 2·5 mm. broad, about 1·5 mm. thick.

Hypocotyl terete, pink above soil, spreading into a flange at base, 1 to 1·3 cm. long, about 1·7 mm. thick at base, 1 mm. at apex.

Cotyledons sessile, oblong-oval, 4 to 4·5 mm. long, 2·5 to 3 mm. broad, upper side green to greenish-red, underside red, often with a raised longitudinal line.

Stem at first slightly angular, becoming terete, green, glabrous. First internode ·5 mm.; second to fifteenth ·5 to 1 mm.

Leaves—No. 1. Abruptly pinnate, petiole 2 to 3 mm., green, glabrous; leaflets three to four pairs, oblong-acuminate, 2 to 3 mm. long, 1 to 2 mm. broad, upperside green, underside very slightly paler; rachis 4 to 5 mm., with terminal seta; stipules reduced to scales.

No. 2. Abruptly bipinnate, petiole 3 to 5 mm., glabrous, with terminal seta; leaflets three to four pairs, oblong-acuminate, the terminal pair sometimes obovate, 1·5 to 3 mm. long, 1 to 2 mm. broad, upperside green; rachis 4 to 6 mm., with terminal seta; stipules reduced to scales.

Nos. 3 to 7. Abruptly bipinnate, petiole 4 to 8 mm., glabrous; leaflets three to five pairs; rachis 4 to 8 mm.

Nos. 8 to 10. These may be phyllodes, or abruptly bipinnate, petiole 5 to 6 mm., with a strong nerve near the lower margin, dilated above to nearly 1 mm. broad; leaflets four pairs.

Nos. 11 to 30. Linear, rigid, pungent pointed phyllodes, 5 to 8 mm. long, about 1 mm. broad, the midrib just below the centre of the lamina. On plants six inches high the phyllodes may be 1 cm. long, 2·5 mm. broad, sometimes slightly recurved.

CALAMIFORMES—(Uninerves).

ACACIA EXTENSA Lindl. Seeds from Western Australia (E. E. Pescott). (Plate XVI, Numbers 4 to 6).

Seeds brownish-black, oblong, apex rounded, to oblong-oval, 4 to 5 mm. long, about 2 mm. broad, 1 to 1·5 mm. thick.

Hypocotyl terete, brownish-red above soil, 1 to 1·8 cm. long, about 1·3 mm. thick at base, about 1 mm. at apex.

Cotyledons sessile, auricled, oblong, apex rounded, 5 mm. long, 2 mm. broad, upperside dark brown to brownish-red, underside pale brownish-red, remaining erect and soon falling.

Stem angular, green, glabrous. First internode ·5 mm.; second to fourth ·5 to 1 mm.; fifth 1 to 2 mm.; sixth and seventh 1 to 6 mm.; eighth 2 to 8 mm.

Leaves—No. 1. Abruptly pinnate, forming an opposite pair, petiole 3 mm. to 1·6 cm., sometimes with a faint gland, green, glabrous; leaflets two pairs, oblong-acuminate to almost oval, 4 to 7 mm. long, 1·5 to 4 mm. broad, upperside green, underside pale pink; rachis 2 to 3 mm., with terminal seta; stipules reduced to scales.

No. 2. Abruptly bipinnate, petiole 1 to 2·8 cm., usually with small gland, glabrous, with terminal seta; leaflets two to three pairs, oblong-acuminate to obovate, 3 to 5 mm.

long, 1·5 to 3 mm. broad, upperside green, underside paler; rachis 5 mm. to 1·1 cm.; stipules reduced to scales.

Nos. 3 to 5. Abruptly bipinnate, petiole 1·3 to 4·2 cm., usually with gland; leaflets two to three pairs; rachis 5 mm. to 1·1 cm. No. 4 may be 1, and No. 5 up to 1·5 mm. broad. In one case No. 4 appeared as an apparent tripinnate leaf, but with a terminal seta on each side of the base of the central pinna; an unusual occurrence.

Nos. 6 and 7. These may be phyllodes, or abruptly bipinnate, petiole 2 to 2·8 cm., usually with gland, dilated up to 2·5 mm. broad, the midrib below the centre of the lamina; leaflets three to four pairs.

When Nos. 6 and 7 occur as phyllodes they may be up to 6 cm. long, and 4 mm. broad, tapering towards the base, midrib distinct, mucronate, with recurved point.

Nos. 8 to 10. Linear phyllodes, slightly rigid, but not as much so as subsequent ones, 2·5 to 8·5 cm. long, 1 to 3 mm. broad. The early phyllodes are flatter and proportionately broader than later ones.

UNINERVES—(Triangulares).

ACACIA HASTULATA Sm. Seeds from Western Australia (E. E. Pescott). (Plate XVI, Numbers 7 to 9).

Seeds pale brown, oblong, 2·5 to 3 mm. long, 1 mm. broad, about ·8 to 1 mm. thick.

Hypocotyl terete, green, 5 mm. to 1 cm. long, 1 mm. thick at base, about ·8 mm. at apex.

Cotyledons sessile, auricled, oblong, apex rounded, 4 to 4·5 mm. long, 1·5 mm. broad, upperside green, underside paler, sometimes remaining until the phyllodes appear.

Stem terete, green, pilose. First internode ·5 mm.; second to eighth ·5 to 1 mm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 6 mm., green, glabrous; leaflets two pairs, oblong-acuminate to obovate, 2 to 3 mm. long, 1 to 2 mm. broad, upperside green; rachis 2 mm. with terminal seta; stipules small, linear.

No. 2. Abruptly bipinnate, petiole 4 mm. to 1·1 cm., with terminal seta; leaflets one to two pairs, oblong-acuminate to obovate, 1·5 to 3 mm. long, 1 to 2 mm. broad; rachis 2 to 5 mm.

Nos. 3 to 5. Abruptly bipinnate, petiole 4 to 9 mm.; leaflets two to three pairs; rachis 2 to 5 mm.; stipules linear, 1 mm.

One No. 3 leaf developed as an abnormal tripinnate leaf, having the basal pair of leaflets transformed into a pair of pinnæ, while the other or apical pair of leaflets remained intact.

Nos. 6 to 8. These may be phyllodes, or abruptly bipinnate, petiole 7 to 9 mm., sometimes dilated to ·5 mm. broad; leaflets two to three pairs.

Nos. 9 to 15. Hastate-lanceolate phyllodes, tapering into a pungent point, 3 to 4 mm. long, the midrib conspicuous and situated just below the centre of the lamina, the upper margin angular and usually bearing a gland.

The young plants bifurcate at an early stage.

UNINERVES—(Brevifoliæ).

ACACIA ACINACEA Lindl. Seeds from Melbourne Botanic Gardens (Cultivated). (Plate XVI. Numbers 10 to 12).

Seeds black, oblong to oblong-oval, about 4 mm. long, 2 mm. broad, 1·5 mm. thick.

Hypocotyl terete, pinkish-green above soil, 1·3 to 1·8 cm. long, 1 mm. thick at base, about ·8 mm. at apex.

Cotyledons sessile, auricled, oblong, apex rounded, 5 mm. long, 2·5 mm. broad, upperside green, underside pale green.

Stem terete, green, glabrous. First internode ·5 mm. second 1 to 2 mm.; third and fourth 2 to 5 mm.; fifth to ninth 3 mm. to 1·3 cm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 6 mm., green, glabrous; leaflets two pairs, oblong-acuminate to obovate, 3 to 6 mm. long, 2 to 4 mm. broad, upperside green, underside pale green; rachis 2 to 3 mm., with terminal seta.

No. 2. Abruptly bipinnate, petiole 5 to 8 mm., green, glabrous, with terminal seta; leaflets two pairs, oblong-acuminate to obovate, mucronate, 3 to 6 mm. long, 1·5 to 2·5 mm. broad, upperside green, underside pale green, venation distinct on underside; rachis 4 to 6 mm., with terminal seta.

Nos. 3 to 5. Abruptly bipinnate, petiole 6 mm. to 1·2 cm., glabrous; leaflets two to four pairs; rachis 5 mm. to 1·2 cm.

Nos. 6 to 8. Abruptly bipinnate, petiole 7 mm. to 1·3 cm., that of No. 8 being sometimes 1·5 mm. broad; leaflets three to five pairs; rachis 7 mm. to 1·4 cm.

Nos. 9 to 15. These may be phyllodes, or abruptly bipinnate, petiole 7 mm. to 1·3 cm. long, up to 3 mm. broad, with a strong nerve along or near the lower margin; leaflets four to five pairs; rachis 8 mm. to 1·1 cm.

Nos. 16 to 20. Obliquely oblong or slightly falcate phyllodes, 1 to 1·5 cm. long, up to 4 mm. broad, often with a small marginal gland, midrib distinct and terminating below the centre, obtuse, with a small recurved point.

UNINERVES—(Angustifoliæ).

ACACIA VISCOSA Schrad. South Australia (Dr. R. H. Pulleine per J. H. Maiden). (Plate XVII, Numbers 1 to 3).

Seeds shiny black, oblong, 5 to 5·5 mm. long, about 2 to 2·5 mm. broad, 1 to 1·5 mm. thick.

Hypocotyl terete, 1 to 1·8 cm. long, about 1·3 mm. thick at base, about ·8 mm. at apex.

Cotyledons sessile, sagittate, oblong, apex rounded, 6 to 7 mm. long, 2 to 2·5 mm. broad, upperside green, underside pale green to reddish-green, with raised centre line, sometimes remaining until the phyllodes appear.

Stem terete, green to brownish-green; glabrous. First internode ·5 mm.; second ·5 to 1 mm.; third and fourth ·5 to 5 mm.; fifth to eighth 2 to 8 mm.

Leaves—No. 1. Abruptly pinnate, petiole 2 to 5 mm., reddish-green, glabrous; leaflets three to four pairs, oblong-acuminate, apical pair often obovate, 3 to 5 mm. long, 2 to 2·5 mm. broad, upperside green, underside pale to reddish-green; rachis 3 to 5 mm., with terminal seta; stipules reduced to scales.

No. 2. Abruptly bipinnate, petiole 7 to 9 mm., green, glabrous to pilose, with terminal seta; leaflets three pairs, oblong-acuminate, apical pair often obovate, usually mucronate, 2 to 4 mm. long, 1·5 to 2 mm. broad, upperside green; rachis 5 to 6 mm., with terminal seta; stipules reduced to scales.

Nos. 3 and 4. Abruptly bipinnate, petiole 7 mm. to 1·3 cm.; leaflets three to five pairs; rachis 4 to 8 mm.

No. 5. This may be a phyllode, or abruptly bipinnate, petiole 8 mm. to 1·6 cm., sometimes dilated to 2 mm. broad, midrib slightly below centre of lamina; leaflets two to five pairs; rachis 5 to 6 mm.

Nos. 6 to 10. Lanceolate phyllodes, with recurved point, 2 to 3·5 cm. long, 3 to 6 mm. broad, tapering very much towards the base, often with small gland on upper margin, resinous, with distinct midrib, often with a second and finer vein above and extending about half the length of the blade but rarely traceable almost to the end. This feature also occurs in seedlings of *A. stricta*,[1] though the mature leaves have but one nerve.

UNINERVES—(Racemosæ).

ACACIA SUBCÆRULEA Lindl. Western Australia (Cultivated Centennial Park, Sydney, J. H. Maiden). (Plate XVII, Numbers 4 to 6).

Seeds brown, oval, 4 mm. long, 3 mm. broad, 1·5 mm. thick.

Hypocotyl terete, pale to brownish-red and red, spreading into flange at root, 1·3 to 2 cm. long, 1 mm. thick at base, about ·7 mm. at apex.

Cotyledons sessile, slightly auricled, oval-oblong, 5 to 6 mm. long, 3·5 mm. broad, upperside at first yellowish-green, becoming green, underside reddish-brown, with one or two raised lines.

Stem at first angular, becoming terete in the lower portion, reddish in lower portion, greyish-green in upper portion, glabrous. First internode ·5 mm.; second ·5 to 1 mm.; third 1 to 2 mm.; fourth to ninth 1 mm. to 1·3 cm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 5 mm., red, glabrous; leaflets three to four pairs, oblong-acuminate, the apical pair obovate to obliquely oval, 4 to 6 mm. long, 1·5 to 3 mm. broad, midrib distinct, upperside green, underside pale red, margins red; rachis 6 to 8 mm., greenish-red, glabrous, with terminal seta; stipules reduced to scales.

No. 2. Abruptly bipinnate, petiole 5 to 8 mm., red, glabrous, with terminal seta; leaflets three to four pairs, 2 to 4 mm. long, 1 to 2 broad, oblong to obovate, the apical pair usually obovate, the pinna often lyrate, upperside green, underside reddish-green to red; rachis 6 to 8 mm., red, with terminal seta; stipules reduced to scales.

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[1] This Journal, Vol. L, 150, (1916).

Nos. 3 to 6. Abruptly bipinnate, petiole 5 mm. to 3·1 cm., sometimes dilated to 5 mm. broad in the case of No. 6, often red, glabrous; leaflets three to six pairs, chiefly obovate, and in the case of No. 4 may be from 2 to 7 mm. long, and 1 to 4 mm. broad; rachis 6 mm. to 2·2 cm.

Nos. 7 and 8. These may be phyllodes, or abruptly bipinnate, petiole 1·1 to 2·5 cm., sometimes dilated to 6 mm. broad, midrib distinct; leaflets four to five pairs; rachis about 8 mm.

Nos. 9 to 12. Lanceolate phyllodes, up to 4 cm. long, 7 mm. broad, mucronate, slightly glaucous.

PLURINERVES—(Armatæ).

ACACIA UROPHYLLA Benth. Western Australia (E. E. Pescott). (Plate XVII, Numbers 7 to 9).

Seeds shiny black, oblong to oblong-oval, 3 mm. long, 1·5 mm. broad, about 1 mm. thick.

Hypocotyl terete, pinkish-green, suddenly constricted above the soil, 1 to 2 cm. long, 1 mm. thick at base, about ·5 mm. at apex.

Cotyledons sessile, oblong, apex rounded, 3·5 mm. long, 1·5 mm. broad, upperside light green, underside yellowish-green, remaining erect and soon falling.

Stem angular, pilose to hirsute, brownish-green. First internode ·5 mm.; second about 1 mm.; third and fourth 1 to 3 mm.; fifth and sixth 1 to 7 mm.; seventh to ninth 4 mm. to 1 cm.

Leaves—No. 1. Abruptly pinnate, forming an opposite pair, petiole 2 to 3 mm. often channelled above, green, glabrous; leaflets two pairs, oblong-acuminate, 4 to 5·5 mm. long, 1·5 to 2·5 mm. broad, upperside green, underside pale green; rachis 2 mm., with terminal seta; stipules small.

Nos. 2 to 4. Abruptly bipinnate, petiole 3 mm. to 1·1 cm., sometimes with a small gland in the cases of Nos. 3 and 4, with terminal seta; leaflets three to five pairs, oblong-acuminate to oblong-oval to obovate, 3 to 8 mm. long, 1·5 to 4 mm. broad; rachis 4 mm. to 1·1 cm.; stipules small.

Nos. 5 to 9. These may be phyllodes, or abruptly bipinnate, petiole 5 mm. to 1·6 cm., often with small gland, pilose, dilated in the case of No. 9 to 1·5 mm., with strong nerve along lower margin, the upper margin nerve-like; leaflets four to five pairs; rachis 4 mm. to 1·7 cm.; stipules 1 to 3 mm.

Nos. 10 to 12. Ovate phyllodes, with two strong nerves confluent at the base and almost so at the apex, and with a third nerve above, extending to nearly the middle of the phyllode.

The transition from leaf to phyllode is usually very sudden in this species, and leaf No. 6 may have a petiole less than ·5 mm. broad, while No. 7 may be a phyllode 1·5 cm. broad.

PLURINERVES—(Falcatæ).

ACACIA BURROWI Maiden.[1] Seeds from Eidsvold, Queensland (Dr. T. L. Bancroft per J. H. Maiden). (Plate XVIII, Numbers 1 to 3).

Seeds shiny black, oblong, 5 to 6 mm. long, 2 to 2·5 mm. broad, 1 to 1·5 mm. thick.

Hypocotyl terete, pink to brownish-red above soil, 1·7 to 2·9 cm. long, 1·5 mm. thick at base, about ·7 to ·8 mm. thick at apex, spreading into a flange at base.

Cotyledons auricled, oblong, 7 mm. long, 2·5 mm. broad, upperside green to greenish-red, underside greenish-red to red, with one or more raised lines and protuberances.

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[1] This Journal, Vol. LIII, 227, (1919).

Stem terete, brownish-green, hirsute to pubescent. First internode ·5 mm.; second and third ·5 to 1 mm.; fourth and fifth 2 to 3 mm.; sixth to eighth 3 mm. to 1 cm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 7 mm., brownish-red, pilose to hirsute; leaflets two to three pairs, oblong-acuminate, 5 to 8 mm. long, 2 to 3 mm. broad, the apical pair usually smallest, midrib prominent on both sides, upperside at first greenish-red, becoming green, underside deep red, margins sometimes ciliate; rachis 3 to 7 mm., pilose, with terminal seta; stipules small, acuminate.

No. 2. Abruptly bipinnate, petiole 8 mm. to 1·3 cm., pilose, with terminal seta; leaflets two to three pairs, obliquely oblong-acuminate, 2 to 5 mm. long, 1 to 2 mm. broad, upperside green, underside greenish-red, margins red, mucronate; rachis 4 to 7 mm., pilose; stipules about 1 mm. long.

Nos. 3 and 4. Abruptly bipinnate, petiole 7 mm. to 1·6 cm., sometimes slightly dilated up to 1 mm. broad, and showing a strong nerve along the lower margin and one or two very fine veins above, pilose; leaflets three to five pairs, slightly smaller than those of No. 2, underside sometimes reddish-green; rachis 4 to 9 mm.

Nos. 5 and 6. These may be phyllodes, or abruptly bipinnate, petiole 2·4 to 3·5 cm., sometimes dilated to 5 mm. broad, tapering at both ends and especially towards the base, the lamina being divided into three almost equal parts by two nerves, the lower one the more prominent, the rest of the blade being finely striate with parallel veins, the margins ciliate; leaflets five to six pairs; rachis 8 mm. to 1 cm.

Nos. 7 to 9. Narrow lanceolate, slightly falcate phyllodes, up to about 5 cm. long and 7 mm. broad, finely striate with parallel veins and three fairly prominent nerves, the centre one the most definite and apparently corresponding with the lower nerve of Nos. 3 and 4, margins slightly ciliate.

BIPINNATÆ—(Pulchellæ).

ACACIA PULCHELLA R.Br. Seeds from Western Australia (E. E. Pescott). (Plate XVIII, Numbers 4 to 6).

Seeds shiny brown, obovate to oval, 2 mm. long, 1 mm. broad, 1 mm. thick.

Hypocotyl terete, reddish-brown to red above soil, 1·5 to 3·5 cm. long, 1 mm. thick at base, about ·5 mm. at apex.

Cotyledons sessile, oblong to oblong-obovate, 2·5 to 3 mm. long, 1 to 1·5 mm. broad, upperside green, underside pale green to reddish-brown, soon falling.

Stem green, pilose to hirsute. First internode ·5 mm.; second 1 to 5 mm.; third 2 to 3 mm.; fourth to sixth 2 mm. to 1 cm.; eighth to tenth 4 mm. to 1·2 cm.

Leaves—No. 1. Abruptly pinnate, forming an opposite pair, petiole 2 to 5 mm., green, glabrous; leaflets two pairs, linear, oblong-acuminate, 3 to 5 mm. long, 1 mm. broad, upperside sometimes at first reddish-green, becoming green, underside pale green to reddish-brown; rachis 1 to 2 mm., with terminal seta; stipules small.

Nos. 2 and 3. Abruptly bipinnate, petiole 5 to 9 mm., glabrous to pilose, with terminal seta; leaflets three to four pairs, oblong, the apical pair sometimes obovate, 2 to 3 mm. long, 1 to 1·5 mm. broad; rachis 3 to 4 mm., with terminal seta; stipules linear, 1 mm. long.

Nos. 4 to 8. Abruptly bipinnate, petiole 5 mm. to 1·4 cm., glabrous to pilose and hirsute, with terminal seta up to 1 mm. long; leaflets four to seven pairs; rachis 5 to 8 mm., glabrous to pilose.

Nos. 9 to 11. Abruptly bipinnate, with only one pair of pinnæ, petiole 4 to 8 mm.; leaflets four to seven pairs;

rachis 6 mm. to 1 cm.; an axillary spine may appear with Nos. 9 and 11.

Nos. 12 to 14. Abruptly bipinnate, with one pair of pinnæ, petiole 1 to 4 and rarely 6 mm.; leaflets 5 to 7 pairs; rachis 7 mm. to 1 cm.; sometimes with axillary spine.

Nos. 15 and 16. Abruptly bipinnate, petiole ·5 to rarely 3 mm., leaflets six and seven pairs; rachis 6 to 9 mm.

Nos. 17 to 25. Abruptly bipinnate, petiole usually less than 1 mm.; axillary spines up to 8 mm., light reddish, sometimes in pairs.

It is remarkable that the length of the petiole diminishes rapidly after leaf about No. 10 is passed, and after leaf No. 16 the petiole is so short that without care a bipinnate leaf might be mistaken for an opposite pair of simply pinnate leaves.

The stems of two seedlings recently sent to me by Mr. W. M. Carne from Mount Henry, Canning River, Western Australia, are hirsute to pubescent, petioles and rachises hirsute, the margins and the undersides of midribs of leaflets sprinkled with hairs.

BIPINNATÆ—(Pulchellæ).

ACACIA PENTADENIA Lindl. Seeds from Western Australia (E. E. Pescott). (Plate XIX, Numbers 1 to 3).

Seeds shiny light brown, oblong to oblong-oval, about 3 mm. long, 1·5 to 2 mm. broad, 1 mm. thick.

Hypocotyl terete, dark purple above soil, 1·6 to 3·3 cm. long, 1 mm. thick at base, about ·6 mm. at apex, spreading into flange at base.

Cotyledons sessile, slightly auricled, oblong, apex rounded, 4 mm. long, 2 mm. broad, remaining vertical, upperside green underside purple.

Stem at first angular, becoming terete, green, glabrous. First internode ·5 mm.; second to fourth 4 mm. to 1 cm.; fifth to eighth 4 mm. to 1·4 cm.

Leaves—No. 1. Abruptly pinnate, forming an opposite pair, petiole 4 to 5 mm., green, glabrous; leaflets two pairs, oblong-acuminate, 3 to 5 mm. long, 1 to 1·5 mm. broad, upperside green, underside paler; rachis 1 to 2 mm., with terminal seta.

No. 2. Abruptly bipinnate, petiole about 7 mm., pilose, with terminal seta; leaflets four to five pairs, oblong-acuminate, the apical pair obovate, 2 to 5 mm. long, 1 to 2 mm. broad; rachis 7 to 9 mm.

Nos. 3 and 4. Abruptly bipinnate, petiole 3 to 6 mm., often with gland on upper margin, pilose; leaflets six to eight pairs in the case of No. 3, eight to thirteen pairs in No. 4; rachis 9 mm. to 2 cm.

Nos. 5 and 6. Abruptly bipinnate, with one or two pairs of pinnæ in the case of No. 5, two to three pairs in the case of No. 6, petiole 4 to 7 mm. where there is only one pair of pinnæ, where there are two or three pairs the common petiole may be 9 mm. to 1·7 cm., with gland at base of each pair of pinnæ, pilose; leaflets eleven to twenty pairs; longest pinnæ 1·5 to 3·5 cm.

Nos. 7 and 8. Abruptly bipinnate, with two to five pairs of pinnæ, the basal pair small, common petiole 8 mm. to 2·2 cm., with gland at base of each pair of pinnæ, glabrous to pilose; leaflets up to from seventeen to twenty-six pairs, oblong-acuminate to ovate; pinna 2·5 to 3·8 cm.

On a plant fifteen inches high are leaves with seven pairs of pinnæ, including the short basal pair, and up to twenty-nine pairs of ovate leaflets on one pinna; common petiole up to 7 cm., length of pinna up to 6 and 7 cm.; two to five pairs of leaflets on basal pair of pinnæ.

EXPLANATION OF PLATES.

PLATE XVI.

Acacia siculiformis A. Cunn.

1. Cotyledons. Eaglehawk Neck, Tasmania, (Miss M. F. Cambage).
2. Pinnate leaf (detached), bipinnate leaves and phyllodes.
3. Pod and seeds.

Acacia extensa, Lindl.

4. Cotyledons and tips of opposite pair of pinnate leaves. Western Australia, (E. E. Pescott).
5. Opposite pair of pinnate leaves, bipinnate leaves and phyllodes.
6. Seeds.

Acacia hastulata, Sm.

7. Cotyledons and pinnate leaf. Western Australia, (E. E. Pescott).
8. Pinnate leaf, bipinnate leaves, phyllodes and root nodules.
9. Seeds.

Acacia acinacea, Lindl.

10. Cotyledons and pinnate leaf. Melbourne Botanic Gardens, (Cultivated).
11. Pinnate leaf, bipinnate leaves and phyllodes.
12. Pod and seeds.

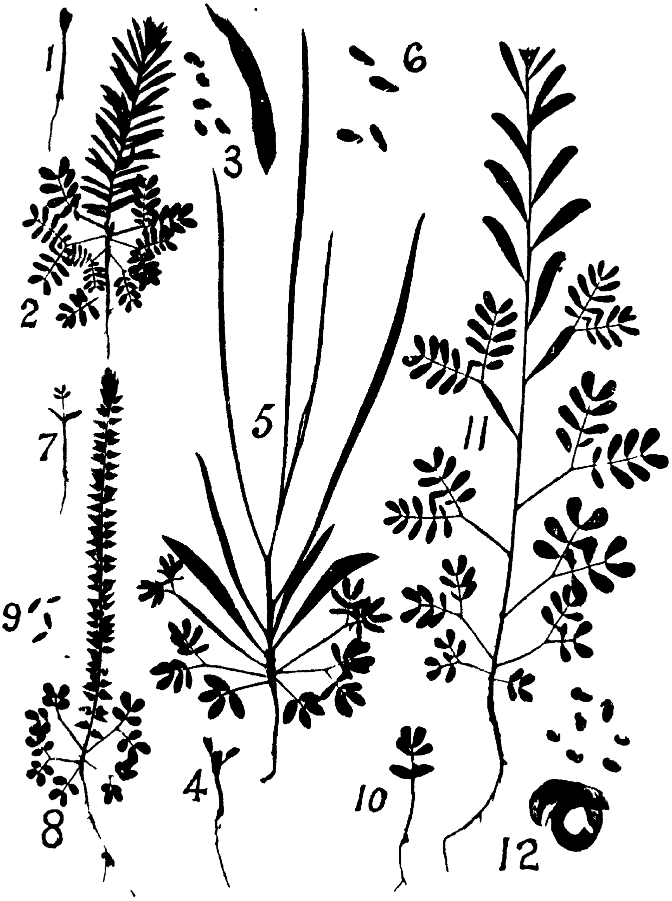
PLATE XVII.

Acacia vicosa, Schrad.

1. Cotyledons. South Australia, (Dr. R. H. Pulleine).
2. Pinnate leaf, bipinnate leaves and phyllodes.
3. Seeds.

Acacia subcœrulea, Lindl.

4. Cotyledons and pinnate leaf. Western Australia, (Cultivated, Centennial Park, Sydney, J. H. Maiden).
5. Pinnate leaf, bipinnate leaves and phyllodes.
6. Pod and seeds.


1
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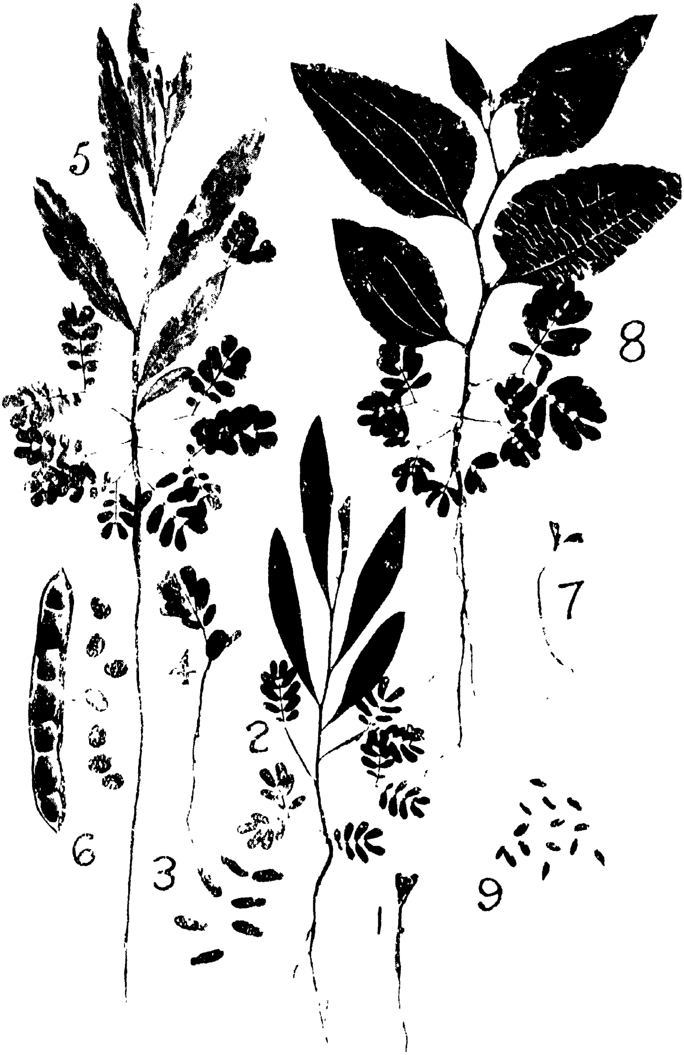
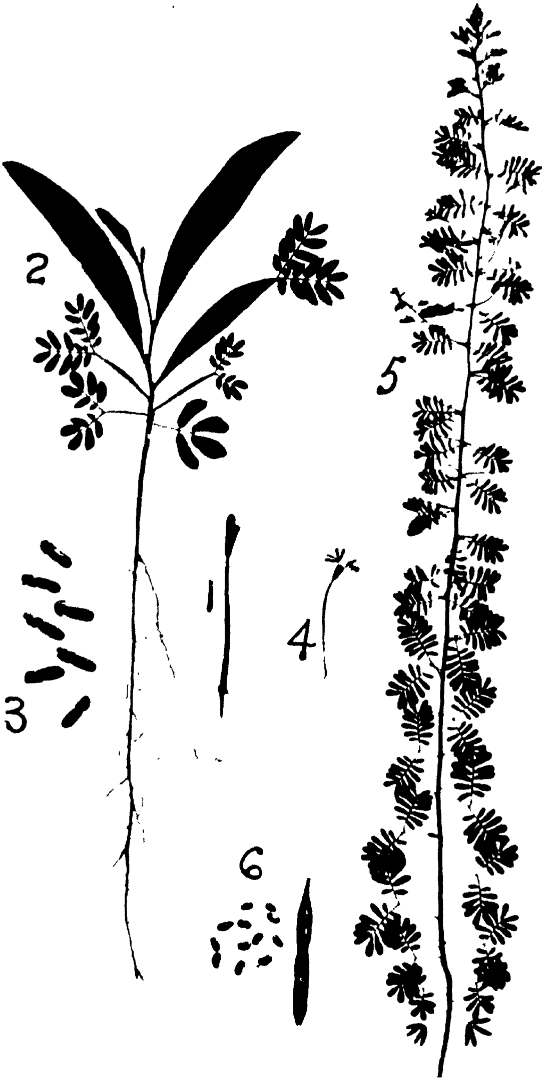
Acacia iculiformis (1 – 3); *A. extensa* (4 – 6); *A. hastulata* (7 – 9) *A. acinacea* (10 – 12).

Two-thirds Natural Size.



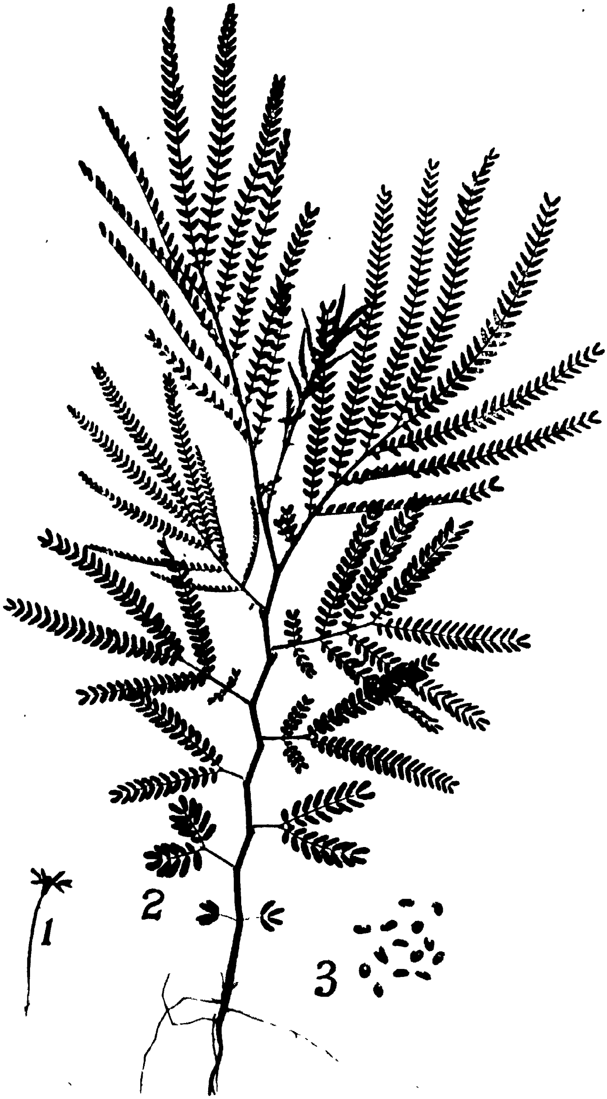
Acacia viscosa (1 – 3); *A. subcærulea* (4 – 6); *A. urophylla* (7 – 9).

Four-fifths Natural Size.



Acacia Burrowi (1 – 3); *A. pulchella* (4 – 6).

Four-fifths Natural Size.



Acacia pentadenia.
Nearly Three-fourths Natural Size.

Acacia urophylla, Benth.

7. Cotyledons and opposite pair of pinnate leaves. Western Australia, (E. E. Pescott).
8. Opposite pair of pinnate leaves, bipinnate leaves and phyllodes.
9. Seeds.

Plate XVIII.

Acacia Burrowi, Maiden.

1. Cotyledons. Eidsvold, Queensland, (Dr. T. L. Bancroft, per J, H. Maiden).
2. Pinnate leaf, bipinnate leaves and phyllodes.
3. Seeds.

Acacia pulchella, R. Br.

4. Cotyledons and opposite pair of pinnate leaves. Western Australia, (E. E. Pescott).
5. Opposite pair of pinnate leaves, bipinnate leaves and phyllodes.
6. Pod and Seeds.

Plate XIX.

Acacia pentadenia, Lindl.

1. Cotyledons and opposite pair of pinnate leaves. Western Australia, (E. E. Pescott).
2. Opposite pair of pinnate leaves, bipinnate leaves and phyllodes.
3. Seeds.

THE ESSENTIAL OIL OF BACKHOUSIA ANGUSTIFOLIA, PART I.

By A. R. PENFOLD, F.C.S.,

Economic Chemist, Technological Museum, Sydney.

[*Read before the Royal Society of N.S. Wales, December 5, 1923.*]

THE botany of this small myrtaceous tree is fully described in Bentham's "Flora Australiensis," Vol. III, page 270. It is a very pretty tree found only in the State of Queensland, fairly widely distributed, but abundant along the Dawson River and around Eidsvold. The investigation of its essential oil was undertaken at the suggestion of Dr. T. L. Bancroft of Eidsvold, Queensland, who kindly furnished at his own expense the excellent supplies of material required for its examination. This gentleman desired a knowledge of its commercial possibilities, but, so far, the author has not been able to suggest a means of utilisation. On account of the essential oil containing about 75% of a previously undescribed phenolic body of poor germicidal value the difficulty of finding an outlet for its commercial utilisation has been further increased. It is not improbable, however, that at a future date it will find use in pharmacology, and experiments are now being instituted in that direction.

The Essential Oil.

The oil obtained by steam distillation from the leaves and terminal branchlets was heavier than water, highly refracting, of a bright brownish orange colour, with a peculiarily characteristic, but pleasant odour. As already stated the principal material used in the investigation was obtained from Eidsvold, Queensland, 585 ℔s. of dried material, containing 12% moisture, cut as for commercial distillation, yielded 1·05% oil.

Through the courtesy of Mr. J. H. Maiden, F.R.S. (Director of the Botanic Gardens and Government Botanist, Sydney) the author was enabled to examine the essential oil of a cultivated tree growing in the Botanic Gardens, Sydney, with very interesting results. A collection of leaves when freshly cut and distilled in November 1922 yielded 0·54% of bright yellow oil, heavier than water, and containing 60% phenol, whilst a second collection made from the same tree in September 1923 yielded only 0·23% of oil lighter than water and containing only 26% phenol. The variation was probably due not so much to the period of the year, but to the dry spell of weather experienced between the months named.

The principal constituent was found to be an undescribed phenolic compound present to the extent of 75%, the remainder consisting of dextro-alpha-pinene, β-pinene, cineol, alcoholic bodies (alpha terpineol identified) sesquiterpene, and a stearoptene (probably a lactone) of melting point 118–119° C.

The principal component is undoubtedly a very remarkable body, and one which at present is very difficult to place on account of its peculiar chemical deportment. Its chemistry is being fully investigated, as time permits, and as it appears to be a representative of the group of essential oil constituents to which Tasmanol[1] and Leptospermol[2] belong, a complete investigation of these two bodies is being carried out in conjunction therewith. A careful consideration, however, of its general behaviour so far observed leads the author to classify it tentatively as a phenol.

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[1] This Journal, Vol. XLVIII, p. 518. [2] Same Journal, Vol. XV, p. 49.

Experimental.

A total of 640½ lbs. of leaves and terminal branchlets, cut as for commercial purpose, yielded on distillation with steam, crude oils possessing the chemical and physical characters shown in table:—

Date.	Locality.	Weight of Leaves.	Yield of Oil.	Specific Gravity $\frac{15}{15}$° C.	Optical Rotation.
27/11/1922	Eidsvold, Q.	289 lbs .	1·01%	1·0414	+ 1·55°
7/9/1923	ditto	296 lbs. (moisture content both lots, 12%.)	1·08%	1·0272	± ·0°
		Cultivated Material.			
20/11/1922	Botanic Gardens, Sydney	28½ lbs.	0·54%	1·0042	- 1·2°
10/9/1923	ditto	27 lbs. (leaves fresh, distilled as soon as cut).	0·23%	0·9599	+ 0·6°

Refractive Index 20° C.	Solubility in 70% alcohol.	Acid No.	Ester No. Cold 2 hours.	Ester No. Hot 1½ hours.	Ester No. after acetylation 1¼ hrs. hot.	Phenol Contents
1·5086	1 in 1 vols.	203·05	203·55	216·64	225·71	75%
1·4973	1 „ 1·4 „	198·30	198·60	207·09	254·14	75%
1·4886	1 „ 1 „	...	...	181·15	213·13	60%
1·4790	...	...	...	...	...	26%

Fractional Steam Distillation.—An interesting example of fractional steam distillation direct from plant material was observed in the examination of the small collection of leaves of the cultivated tree from the Botanic Gardens, Sydney, as exemplified in the following table:—

28·5 lbs. of leaves yielded 33 grams of oil heavier than water, and 37 grams lighter than water, a total of 70 grams.

	Light Oil.	Heavy Oil.
Specific gravity, $\frac{15}{15}$° C.	0·9795	1·0355
Optical rotation	− 0·85°	− 1·6°
Refractive index, 20° C.	1·4808	1·4991
Solubility in 70% alcohol	1 in 1·1 vols.	1 in 1·4 vols.
Phenol contents	44%	80%

The investigation of the crude oil was best conducted by first resolving it into "phenol" and "non-phenol" portions by means of 8% sodium hydroxide solution, the Queensland oil being used throughout the investigation :—

Sample, 27/11/1922.—500 c.c. crude oil were shaken with 1500 c.c. 8% sodium hydroxide solution, and the unabsorbed oil, 140 c.c. separated.

Sample, 7/9/1923.—1000 c.c. crude oil on similar treatment with 2000 c.c. 8% sodium hydroxide solution yielded 305 c.c. unabsorbed.

The alkaline liquors were later worked up by acidulating with dilute sulphuric acid solution and separation and purification of the liberated phenol. The unabsorbed portions, being somewhat turbid, were subjected to steam distillation when the suspended matter responsible for same was left behind in the flask. Subsequent examination showed it to be a non volatile stearoptene (probably a lactone) which had been held in solution by the phenol and thrown out when the latter was removed.

The non-phenolic portions after steam distillation were almost colourless mobile oils resembling in general physical characters, odour, etc., cineol Eucalyptus oils. On examination the following results were obtained:—

	Sample 27/11/1922.	Sample 7/9/23.
Specific gravity, $\frac{15}{15}$° C.	0·9081	0·9034
Optical rotation	+ 6·1°	+ 8·25°
Refractive index, 20° C.	1·4655	1·4668
Solubility in 70% alcohol	...	1 in 8 vols.
Cineol (Resorcin method)	50%	30%

These on repeated fractional distillation gave the following fractions:—

Sample, 27/11/1922.	Volume.	Specific gravity	Optical rotation	Refractive index	Cineol (Resorcin method)
163 - 166° C. (764 mm.)	8 c.c.	0·8889	+ 13·3°	1·4627	50 %
166 - 169°	12½ „	0·8959	+ 10·5°	1·4623	60 „
169 - 173°	32½ „	0·9017	+ 8·1°	1·4618	67½ „
173 - 177°	29 „	0·9097	+ 5·0°	1·4617	87½ „
177 - 185°	13 „	0·9129	+ 3·9°	1·4621	90 „
residue.	8 „	0·9189	+ 2·5°	1·4700	
75 - 90° C. at 10 mm.	5 „	0·9130	+ 3·4°	1·4671	
90 - 108° do.	13 „	0·9184	+ 0·8°	1·4748	
108 - 135° do.	5 „	0·9232	- 0·30°	1·4878	
Sample, 7/9/1923.					
63 - 75° C. at 20 mm.	135 „	0·8965	+ 10·35°	1·4631	62½ „
75 - 85° do.	19 „	0·9074	+ 5·3°	1·4631	87½ „
85 - 100° do.	19 „	0·9116	+ 3·15°	1·4674	
100 - 106° do.	7 „	0·9156	+ 0·4°	1·4740	
96 - 100° C. at 10 mm.	9 „	0·9194	- 0·3°	1·4810	
110 - 130° do.	5 „	0·9351	+ 3·5°	1·4972	

(Specific gravities taken at 15/15° C., and refractive indices at 20° C.)

Determination of Terpenes.—Fractions Nos. 1 and 2 of sample 27/11/1922 containing 50% and 60% cineol (resorcin method) respectively were mixed and the cineol removed by means of 50% resorcin solution. The unabsorbed oil was separated and purified by steam distillation. On distillation the greater portion boiled at 156 - 160° C. at 766 mm. had specific gravity $\frac{15}{15}$° C. 0·8642, optical rotation + 21°, refractive index, 20° C. 1·4660, and readily yielded a nitrosochloride, which on purification melted sharply, with decomposition at 109° C.

The first and second fractions of sample 7/9/1923, were also worked up in a similar manner, and the cineol free portion distilled with the following result:—

Boiling Point at 766 mm.	Specific gravity at 15/15° C,	Optical rotation	Refractive index 20° C.
155 - 157° C.	0·8641	+ 25·5°	1·4662
158 - 160° C.	0·8652	+ 23·7°	1·4668
160 - 166° C.	0·8666	+ 20·75°	1·4671

α-Pinene.—The portion distilling at 155 – 157° C. was oxidised with potassium permanganate by the method previously described in this Journal, Vol. LVI, (1922), page 195. The crude pinonic acid isolated therefrom was converted directly to the semicarbazone, which on purification, melted at 207° C. The presence of α-pinene was therefore confirmed.

β-Pinene.—The third fraction boiling at 160 – 166° C. was oxidised with alkaline potassium permanganate[1] when a small quantity of a sparingly soluble sodium salt was obtained. This on decomposition with dilute sulphuric acid and extraction with benzene yielded a solid acid of melting point 121° C. Repeated purification failed to raise the melting point and though lower than usual (127° C.) sufficient evidence was available to demonstrate the presence of β-pinene.

Determination of Cineol.—The resorcin washings from the terpenes referred to above were subjected to steam distillation and the regenerated cineol purified by distillation at 762 mm. It boiled at 175 – 177° C., had specific gravity $\frac{15}{15}$° C. 0·9289, was inactive, and gave refractive index 20° C. 1·4589. Its identity was confirmed by its behaviour with phosphoric acid and the preparation of the iodol derivative which melted at 112° C.

Determination of Alcoholic bodies (alpha Terpineol).—The eighth fraction (sample 27/11/1922) was redistilled when a portion of 7 c.c. boiling at 206 — 214° C. (u.c.) at 765 mm. was obtained. It had specific gravity, 15/15° C. 0·9180, was inactive, and had refractive index 20° C. 1·4749. The fifth fraction (sample 7/9/1923) on redistillation gave a portion distilling at 96—100° C. 4½ c.c., possessing the following constants:—specific gravity 15/15° C. 0·9184, optical rotation – 1·3°, and refractive index 20° C. 1·4781.

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[1] Parry's "Essential Oils," p. 37.

These figures pointed to the fractions being mixtures of bodies, probably mainly alcoholic, of which alpha Terpineol was readily recognised by the preparation of the nitrosochloride melting at 113° C.

Determination of Sesquiterpene.—The quantity of high boiling constituents obtained was altogether too small for purification. The general physical characters and the colour reactions obtained with bromine vapour and sulphuric acid in glacial acetic acid and acetic anhydride solution respectively readily demonstrated the presence of sesquiterpenes, similar in nature to those usually obtained from essential oils of the Myrtaceæ.

Determination of Stearoptene (probably a Lactone).—The residue left after steam rectification of the non-phenol portion of the crude oils was obtained as a brownish resinous powder. On boiling it up with absolute ethyl alcohol and filtering, yellow prismatic crystals separated out on cooling, which on purification melted at 118 – 119° C. 1500 c.c. of the crude oils gave about 4 grams of crystals. They were insoluble in cold 5 to 10% sodium hydroxide solution, but readily dissolved on heating, from which they were reprecipitated on addition of mineral acids. With ferric chloride in alcoholic solution a bright green colour resulted, which changed rapidly to a striking bluish-green colour. The formula appears to be $C_{15}H_{16}O_5$ as indicated by the following combustion and molecular weight results, viz:—

(1) 0·1190 gram gave 0·2851 gram CO_2 and 0·0636 gram H_2O
C—65·34% H—5·93%

(2) 0·1256 gram gave 0·3010 gram CO_2 and 0·0670 gram H_2O
C—65·36% H—5·93%

$C_{15}H_{16}O_5$ requires C—65·22% H—5·8%

Molecular Weight Determinations.

(*a*) A molecular weight determination by the Landsberger boiling point method, using acetone as solvent, gave the following result:—0·5494 gram in 20·5 c.c. acetone elevated the boiling point 0·22° C. M.Wt. = 271.

(b) A determination by the cryoscopic method, using benzene, resulted as follows:—0·3481 gram in 9·8 grams benzene lowered the freezing point of the solvent 0·68° C. M.Wt. = 263. $C_{15}H_{16}O_5$ = 276.

Determination of Phenolic Constituent.—The sodium hydroxide solutions containing the phenolic constituent were repeatedly washed with ether in order to remove all neutral bodies held in solution, from which it was subsequently isolated by means of dilute sulphuric acid solution. The liberated phenol, which constituted about 75% of the crude oils, was taken up in ether, washed with dilute sodium bicarbonate solution, the solvent removed, and its purification effected by repeated distillation at 10 mm.

As thus obtained it was a somewhat viscous liquid, almost colourless, though sometimes possessing a faint lemon tint, with a pleasant and characteristic odour, and giving with ferric chloride in ethyl alcohol solution a brilliant orange-red colouration, thereby strongly resembling leptospermol[1] It was optically active, being slightly lævo-rotatory. On allowing it to remain in contact with metals, such as iron, copper, cobalt, chromium, cadmium, etc. it slowly attacked them giving highly coloured solutions.

A peculiar feature of this constituent is that specimens isolated from the two Queensland consignments differed from each other in physical characters, with the single exception of boiling points which were identical in both samples. It was necessary, therefore, to separate this constituent from other specimens, and the sample obtained from the cultivated tree, as well as an old one in the

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[1] This Journal, Vol. LV, 1921, p. 49—51.

Museum, which had been obtained from material supplied by Dr. Bancroft as far back as 1911, were used for this purpose. (This latter sample agreed well in chemical and physical characters with those of recent date, except that it was of a deep blackish-red colour through having been distilled through a steel coil). The following table gives the constants of the four preparations:—

	No. 1 27/11/1922.	No. 2 7/9/1923.	No. 3 10/9/1923. (Cultivated)	No. 4 1911. (Old Sample)
Boiling point, 10 mm.	122 – 124° C.	123 – 125° C.	123 – 124° C.	122 – 124° C.
Specific gravity $\frac{15^\circ}{15}$ C.	1·1054	1·0900	1·0848	1·0885
Optical rotation	– 0·55	– 4·65	– 4·65	– 4·45°
Refractive index 20° C.	1·5288	1·5130	1·5084	1·5113

The last three agree fairly well among themselves, but the difference between these and the first is difficult of explanation, just at present, because although they all distil almost completely at 122 – 125° C. at 10 mm., there is no evidence available to demonstrate that they do not represent constant boiling mixtures of closely allied bodies. Meantime, the author prefers to consider the phenol of the second consignment as representing a chemical entity. Nos. 3 and 4 were not available in sufficient quantity for as much purification as was possible to give to No. 2. All experimental data below were obtained with No. 2 sample, unless otherwise stated.

The formula appears to be $C_{10}H_{14}O_3$ as indicated by the following combustion and molecular weight results:—

(1) 0·1080 gram gave 0·2602 gram CO_2 and 0·0774 gram H_2O
C—65·70% H—7·96%

(2) 0.1391 gram gave 0·3206 gram CO_2 and 0·0962 gram H_2O
C—65·94% H—7·68%

(3) 0·1150 gram gave 0·2780 gram CO_2 and 0·0814 gram H_2O
C—65·93% H—7·86%

(4) 0·1684 gram gave 0·4051 gram CO_2 and 0·1184 gram H_2O
C—65·61% H—7·81%
$C_{10}H_{14}O_3$ requires C—65·93% H—7·69%

Molecular Weight Determinations.

(*a*) A molecular weight determination by the Landsberger boiling point method, using acetone as solvent, gave the following result:—1·1188 grams in 26 c.c. acetone elevated the boiling point 0·6° C. M.Wt. = 184.

(*b*) A determination by the cryoscopic method, using benzene, resulted as follows:—0·4630 grams in 9·8 grams benzene lowered the freezing point of the solvent 1·27° C. M.Wt. = 186. $C_{10}H_{14}O_3$ = 182.

Reactions.—The phenol is soluble in all ordinary organic solvents, and reacts acid to litmus. It is insoluble in cold sodium carbonate and sodium bicarbonate solutions, but soluble in both on heating to boiling, from which it is regenerated unchanged on addition of mineral acids. Prolonged passage of carbon dioxide gas also partially liberates the phenol from alkaline combinations. It also reacts with semicarbazide acetate and hydroxylamine to form what appear to be ill-defined crystalline derivatives, but these will be dealt with in a subsequent communication. They may, however, be taken as evidence of the presence of a "carbonyl" group. Attempts to prepare a phenylurethane, benzoyl and acetyl derivatives and the introduction of methoxyl groups were unsuccessful. No evidence either of the presence of methoxyl or ethoxyl groups was obtained. It did not yield, under varied experimental conditions, any crystalline derivative with bromine.

The following are the two best derivatives that have so far been observed:—

Ammonium compound, $C_{10}H_{17}O_3N$.—It readily combines with ammonia to form a well defined crystalline body melting at 135–137° C. The phenol of high refractive index

(No. 1), however, forms a compound melting at 153° C., which differs from the three preparations of the other which all melt at the same temperature, and moreover, is different in crystalline appearance.

Preparation.—12 c.c. phenol are covered with 10 – 15 c.c. water in a small porcelain basin and 20 – 25 c.c. concentrated ammonia solution 0·880 added, when a white solid results. It is then warmed on a water bath with gradual addition of small quantities of water until complete solution is effected, when after the lapse of about half an hour the whole mass crystallises, especially if assisted with frequent stirring. When cold the crystals are separated on a Buchner filter funnel, and dried on a porous plate. The crystals are purified by washing with petroleum ether (B.Pt. below 50° C.) in which they are insoluble, and recrystallised from absolute ethyl alcohol. They are soluble in ethyl alcohol, acetone and chloroform, but insoluble in petroleum and ethyl ether. The ammonium compound is readily decomposed by sodium and potassium hydroxide solutions, with evolution of ammonia and regeneration of the phenol unchanged. An estimation of its nitrogen contents was, therefore, most readily made by the decomposition of a known weight with sodium hydroxide solution and the distillation of the ammonia into standard acid, in a similar manner to that of an ordinary Kjeldahl determination :—

(1) 0·8800 grams required 8·8 c.c. semi-normal acid to neutralise the liberated ammonia—7% nitrogen.

(2) 0·7311 grams ditto 7·35 c.c. semi-normal acid—7·04% nitrogen.

$C_{10}H_{17}O_3N$ requires 7·04% nitrogen.

Copper Compound, $(C_{10}H_{12}O_3)_2$ Cu.—The phenol does not liberate carbon dioxide from ammonia carbonate, sodium carbonate, sodium bicarbonate, nor from any of the commoner metallic carbonates, but its affinity for copper is so great that it possesses the remarkable property of liberating carbon dioxide from copper carbonate at room temperatures.

Preparation.—About 10 grams of the substance is placed in a small porcelain dish and a slight excess of copper carbonate is stirred in. A vigorous reaction takes place immediately and carbon dioxide is rapidly evolved. Within about fifteen minutes the whole is changed to a dry solid of purple colour. It is removed from unchanged carbonate by boiling with ethyl alcohol, from which solvent it is crystallised. As thus obtained it is a purple coloured crystalline powder melting at 193—194° C., all specimens of the phenol yielding the same copper compound. The solution in ethyl alcohol is of an intense greenish-blue colour which matches that of an aqueous solution of malachite green dye.

0·7820 gram of copper compound when decomposed by boiling with dilute hydrochloric acid solution, the liberated phenol extracted by means of ether, and the copper precipitated gravimetrically in the usual manner with sodium hydroxide solution, yielded 0·1467 gram CuO, equivalent to 14·92% Cu. $(C_{10}H_{12}O_3)_2Cu$ requires 14·89% Cu.

Oxidation.—20 c.c. phenol were shaken with 60 grams powdered potassium permanganate, 8 grams caustic potash, 1200 c.c. water and 1000 grams ice until reaction was completed. The potassium salts of acetic and carbonic acids were the only products that were isolated. On treating the crude potassium salts with absolute ethyl alcohol almost pure potassium acetate was obtained after removal of solvent, and its identity established by the usual qualitative reactions. Identical results were obtained with the two different specimens of phenols isolated from the Queensland oils. The silver salts were accordingly prepared from the volatile acids resulting from the oxidation of both specimens with the following results:—

(1) 0·6252 gram gave 0·4038 gram silver—64·59%
(2) 0·2486 gram gave 0·1608 gram silver—64·68%
Silver acetate—64·67%

The further work in progress on this interesting body will be published at a later date.

My thanks are due to Dr. T. L. Bancroft of Eidsvold, Queensland, for his keen interest in these investigations and for his kindness in furnishing the excellent supplies of material; to Mr. J. H. Maiden, F.R.S., Director of Botanic Gardens and Government Botanist, Sydney, and Mr. E. N. Ward, Superintendent, Botanic Gardens, Sydney, for their interest in furnishing supplies of cultivated material; and finally to Mr. F. R. Morrison, A.T.C., Assistant Chemist, for his assistance in these investigations, especially in regard to confirmation of combustion and molecular weight determinations of the new substances.

NOTES ON WATTLE BARKS, PART I.

By M. B. WELCH, B.Sc., W. McGLYNN, and F. A. COOMBS. F.C.S.[1]

[With Plates XX, XXI.]

[Read before the Royal Society of N.S. Wales, December 5, 1923.]

SINCE the extraction of tannin from wattle bark has given tanners a considerable amount of trouble, it was considered that an examination of the bark structure in conjunction with estimations of the tannin and other contents, should be carried out. A number of samples of barks belonging to the Black or Green Wattle, *Acacia decurrens* Willdenow, group, which forms the principal source of bark in this State, have therefore been examined, and it is proposed in this introductory paper to deal principally with the nature and distribution of the tannins present and the bark anatomy. Although the problems connected with the leather forming properties of tannin and its extraction from wattle bark have received a great deal of attention from the Tanning School attached to the Department of Technical Education, Sydney, this does nor apply to the actual distribution of the tannin in the plant tissues. Since the ease of extraction of the tannin depends on the readiness with which it can diffuse out of the tissues it is obvious that the structure of the latter is of importance.

The term "tannin" is used to denote a number of substances possessing somewhat similar properties, and occurring widespread throughout the plant world, being found in the roots, stems, leaves and fruits of the higher plants and even in the filamentous algæ.

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Zimmermann (1896) thus defines tannin: "all those substances which give a blue-black or green-black with iron salts, are commonly designated as tannic acids or tannin. There belong here of the better known compounds, especially pyrocatechin, pyrogallic acid, protocatechuic acid, gallic acid." As defined by Pfeffer, (1903) "tannin is a technical term which has no precise chemical or physiological meaning, for the same microchemical tests with iron salts and potassium bichromate are given by various phenols and phenol compounds, but not by others such as phloroglucin, etc., which have a similar physiological function."

Proctor (1, 1919) on the other hand states that all "tannins give a precipitate or turbidity with gelatine though the sensitiveness of the test is not the same for all tannins. Substances which are like tannins in most other respects but which do not give the gelatine test must be regarded as non-tans."

Tannins may therefore be regarded as products found to occur in plant life, especially in the barks, fruit, wood and leaves. They possess an astringent taste, give greenish or bluish black colourations with iron salts, precipitate gelatine from its solution, give a slightly acid reaction, and combine with the raw hide to produce a leather which has certain chemical and physical properties not common to all kinds of leather.

The tannins are noted for their astringent properties. Villon (1901) describes astringency "as the property of shrivelling the tissues or shutting up the openings of certain organs, as for instance, the papillæ of the tongue, but this is not peculiar to tannins, which however is the astringency par excellence; it is possessed by a large number of styptic salts, such as alum, sulphate of iron, sulphate of zinc, lead acetate and certain acids, such as dilute sulphuric acid, dilute acetic, and gallic acid."

Astringency is a term used to describe the sensation caused by bringing the tongue in contact with certain substances. Although the word is hardly known in the tanning industry, vegetable tannins which cause excessive contraction of the surface of the pelt are sometimes described as being very astringent. In the list of substances mentioned by Villon, *l.c.*, one notes that they possess acid properties and in some cases the power to precipitate gelatine from its solution. Substances which precipitate gelatine probably dehydrate wet animal skin (pelt). Tannins dehydrate pelt with the formation of leather; in this case dehydration of the skin substances is akin to precipitation from solution, and astringency is probably the result of bringing an acid dehydrating substance in contact with cellular or fibrous protein tissue. The dehydration or precipitation of gelatine from its solution is probably caused by the mutual combination of groups in the gelatine and in the tannin molecular aggregates; these groups being the cause of their solubility. That this becomes a complex problem is apparent when we note (Proctor, 2, 1919) that certain substances found as decomposition products of the tannins, catechol and pyrogallol, contain OH groups which have phenolic and alcoholic functions.

The tannins occuring in the wattle bark and dealt with in this paper are only those capable of classification into that group which besides responding to the above definition, are absorbed by hide powder according to the regulations laid down by the Society of Leather Trade Chemists.[1]

Perhaps the commonest empirical test for tannins is the use of iron salts, producing certain colour reactions, but this has the disadvantage that the colourations are given by other substances, which do not behave as tannins.

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[1] Proctor. Leather Trades Pocket Book.

Potassium bichromate, first recommended by Sanio, was found to be the most satisfactory method of precipitating the tannin in the cells of the tissues in which it occurs. The brownish precipitate is insoluble in water, alcohol, etc. In concentrated aqueous solutions the penetration is quite satisfactory when the bark is treated in small pieces, measuring about 1 cm. square, and sections cut from treated material can be preserved in canada balsam, or glycerine. Zimmerman *l.c.*, states that according to Nickel (1890) various compounds not related to tannins give similar precipitates with potassium bichromate, but it has been found in this research that bichromates give no precipitate with the soluble non-tans left after a hide powder analysis of various samples of wattle bark, *i.e.*, after all the tannins have been absorbed. This is a most important point since it can reasonably be assumed that the precipitate formed in the cells is due to the combination of the tannin and bichromate. As will be shown later potassium bichromate has also the advantage of giving a precipitate in very dilute tannin solutions. Since pyrogallol does not occur in these tannins the insoluble precipitate in this case is not likely to be the oxidation product purpuro-gallol mentioned by Moeller (*c.f.* Zimmerman, *l.c.*). Chromic acid was not found to be so satisfactory as the bichromate.

The gelatine test is regarded by leather trade chemists as the most useful method of detecting the presence of tannin in dilute solutions, but owing to its viscosity it is obviously unsuited for microchemical work. The solution contains 10g gelatine and 100g salt in one litre of water. Proctor (1, 1919) states in reference to gelatine that a precipitate is obtained in extremely dilute solutions of gallotannin, or fruit tannin, while the bark tannins give the test if the solutions are not too weak, pine bark and gambier being the least sensitive. Other micro-chemical tests for tannins are described in the various text books on the subject, such reagents as osmic acid, chromic acid, ammonium molybdate, sodium tungstate, alkaline carbonates, methylene blue and certain alkaloids being found more or less satisfactory.

It was found by experimental work that the gelatine and bichromate tests for tannin do not always give constant results. Apparently with some solutions the sensitiveness of the gelatine reaction with the tannins varies to a considerable extent. We obtained a turbidity with gelatine in a solution of one part of tannin in 100,000 parts of water, but with other solutions from different barks we were unable to get any reaction with a solution of one in 25,000. This apparently is in accordance with results obtained by Thomas and Frieden (1923) who found that the hydrogen ion concentration of the solution is an important factor, controlling to a certain extent the reaction of gelatine with tannin in dilute solutions, and probably our failure to secure recognition of tannin in solutions of one in 25,000 was due to the fact that, with dilution, the hydrogen ion concentration fell below the figure they give as the most suitable for the recognition of tannin in wattle bark. The authors found that the best ratio of tannin to gelatine is two to one, and when the hydrion concentration for wattle barks was adjusted to pH = 4·5 to 4, then it was possible to obtain a recognition of one in 200,000. Without adjusting the acidity they only obtained a recognition of one in 20,000 for the same solution. These variations in our results were not so noticeable with the bichromate test, a recognition of one part of tannin in 25,000 to 50,000 being obtained by adding a few drops of a saturated aqueous solution of bichromate of potash to a dilute solution of the soluble matter obtained from various barks. The turbidity was only obtained after standing for some minutes in very weak concentrations.

It is usually accepted that the tannin is more or less in solution in the cell sap and although after the death of the cell, diffusion may occur into the cell wall, it is normally confined within the protoplasmic membranes, and although the tannin undoubtedly possesses the property of precipitating albuminoids it is obvious that it may not necessarily affect protoplasm.

Lloyd (1922) puts forward the theory that two substances are present in the vacuole of the tannin cell, namely, the tannin itself, and another substance with the physical properties of a gel. He also points out that after extraction of oak bark with alcohol the tannin cells are still filled with insoluble material which contains tannin, and he describes this mode of occurrence as the tannin mass, which consists of a complex of substances, tannin being one. Lloyd *l. c.*, quotes Van Wisselingh (1910) as having confirmed the earlier research of Wigand in concluding that the tannin is an essential factor in plant metabolism, being concerned in the building up of cellulose. When the concentration is high, it seems that the view expressed by Lloyd *l.c.*, is correct, namely that the tissues are approaching death and that the tannin does not again enter into the metabolism of the plant. The benefit obtained by a protective device consisting of an outer zone of cells containing a very high tannin concentration cannot be overlooked. (*c.f.* Stahl, 1888) In all the Acacia barks so far examined, it has been found that the tannin concentration undoubtedly reaches a maximum towards the outer corky layers. Recent work seems to indicate that tannin is not always a protoplasmic poison, but where it is, it is probably held by a strongly adsorbing body, but where non-toxic, a weaker adsorbing body would allow of its more ready use. This body in certain cases being identified as a carbohydrate. (*c.f.* Lloyd, *l.c.*)

The word "bark" is used here to define the whole of the tissues outside the woody cylinder of the tree, since this portion is always referred to when the term "wattle bark" is used. The definition is more often given as that portion of the outer tissues consisting of the dried up, cortical, and sometimes vascular cells, cut off from the inner living portion by the phellogen or cork cambium, together with the outer corky layers, the whole being principally concerned in the reduction of transpiration, and the furnishing of protection against mechanical injury to the inner conducting tissue.

Dealing first with the anatomical structure it is found that the bark consists primarily of the secondary phloem, a broad zone of conducting tissue extending from the cambium, adjacent to the wood, as far outward as the cortical tissue, the latter being composed of a comparatively narrow area of thin walled cells or parenchyma, outside which is in older bark a narrow band of cork cells, or an epidermal layer in younger barks.

The conclusion arrived at by Coester, (1894) namely, that the outer limit of the bast formed by a composite ring of sclerenchyma, (*i.e.*, thick walled cells) is a characteristic feature of the Mimoseæ, in which group the Acacias are included, is in the majority of cases correct for the barks of the *Acacia decurrens* group. In certain cases, however, the ring has been found to be broken, and therefore cannot be regarded as a specific character. Similarly it has been found that although the cork cells are usually developed superficially as pointed out by Coester, *l.c.*, the phellogen not arising much below the epidermis yet in certain bark specimens examined, undoubted evidence was found that the cork cells may develop well within the sclerenchymatous ring, proving that a phellogen may subsequently arise in a deep seated position. The cork cells are flattened radially with moderately thick walls, the actual thickness of the periderm being small, as a rule not more than 0·2 mm. The outer bark surface is often scaly due to the separation of the masses of cork cells, caused by the increase in circumference of the growing tree.

Both the sieve tubes and companion cells which occur in tangential bands between rows of phloem parenchyma cells, collapse within a short distance of the cambium. These areas of collapsed cells are persistent throughout the secondary phloem, (Plate XXI, fig. 4) and possess a strong affinity for stains, but the parenchyma cells remain unchanged except for an increase in size. The amount of space occupied by these collapsed tissues in a mature bark is unimportant and they can therefore have little effect upon the tannin content of the whole.

The phloem parenchyma cells which contain a large percentage of the total tannin measure about 0·037 mm. in length, being directed longitudinally, by about 0·01 mm. in diameter, and are almost circular in cross section. As they become further removed from the cambium, due to the growth of newer cells the increase in size becomes more marked, until finally they may measure 0·04 mm. in diameter often becoming flattened, with the longer axis directed tangentially. There is no proportional increase in vertical length.

Of even greater importance in their influence on the tannin yield are the medullary rays, which are either uniseriate or multiseriate, broadening considerably in the outer portion of the bark, with a considerable increase in the cell size to about 0·05 mms. in maximum diameter. Near the cambium the longest axis is directed radially; the older cells are flattened tangentially.

The degree of development of the bast fibres is however of considerable importance in its influence on the tannin content, for several reasons. In the first place the cell walls are extremely thick, the lumen in the older cells almost disappearing, and since the specific gravity of this lignified tissue is about 1·6, the insoluble matter in a comparatively small amount of fibre is equivalent in weight to that present in a much larger amount of thin walled tannin bearing cells. Thus a bark containing even a moderate development of fibre has an increased percentage of insolubles, and a lower percentage of total solubles, including tannin, on analysis. Secondly, since no tannin is shown by any microchemical test to be present in the cell wall or in the lumen of these fibre cells, they can yield practically nothing on extraction. In certain barks examined in which the tannin content was low the development of bast fibre was exceptionally high, and *vice versa*, in a bark showing a tannin content of 46·93%[1] the amount of fibre was extremely low. In the inner portion of the secondary phloem the area of the fibre groups in cross section may amount to as much as 50% in some barks. The diameter of the bast fibres is small, averaging about 0·009 mms., the maximum size of the groups being in the vicinity of 0·6 mm. in a tangential direction by about 0·1 mm. in width. More or less surrounding the fibre group is a single row of short thick walled crystal bearing cells the contents being apparently calcium oxalate.

Surrounding the vascular tissue is usually a more or less complete chain of stone cells, (sclereides), irregular in shape with heavily lignified walls and containing no tannin. The cortical tissues outside this zone are tannin bearing, and usually chlorophyll is present. The outer corky cells of the periderm are small, with thick suberised walls, the brown contents evidently consisting principally of phlobaphenes. The phelloderm is scarcely developed. It has been pointed out that in certain cases the phellogen may develop in a deep seated position, but this is rare. Even in barks of considerable thickness the epidermis may still be persistent in some cases. Occasionally a row of pockets containing what is evidently gum occur concentrically in the secondary phloem. The contents give no reaction with potassium bichromate when the tissue is treated in bulk; they are then insoluble in water. The cavity is apparently formed by the disintegration of the phloem tissues.

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[1] As far as we are aware this is the highest recorded analysis of any bark of the *A. decurrens* group. The complete analysis was, tannin = 46·93%; soluble non tannins = 9·85%; insolubles = 34·45; moisture = 8·77%.

A whitish glaucous deposit of wax is occasionally found in the barks of some trees. The powdery substance is partly soluble in 100 per cent. alcohol, and is soluble in chloroform.

The distribution of the tannin is principally in the outer parenchymatous cells of the medullary rays, in the primary and secondary cortex, and also in the phloem parenchyma. Plate XX, fig. 1 shows a transverse section of a portion of the bark of *Acacia decurrens* measuring about 4 mms. in thickness. The bark was given the preliminary treatment with potassium bichromate before sectioning. It is seen that the concentration of tannin bearing cells with dark contents, reaches a maximum both inside and outside the narrow clear band of stone cells occurring towards the outer edge.

Plate XX, fig. 2, shows an enlargement of portion of the same section within the lower rectangle near the cambium. The tannin bearing cells of the phloem parenchyma are usually arranged in short chains at right angles to the medullary rays, the cells of the latter being somewhat elongated and also showing a reaction for tannin. These cells are in each case thin walled; the thicker walled bast fibre groups are already numerous and contain no tannin.

The concentration of these darker cells increases with the distance from the cambium at the right hand edge of the figure. Fig. 3 (Plate XXI) also shows an enlargement of portion of the same section as Fig. 1 (Plate XX), but nearer the outer edge of the bark, as shown in the upper rectangle. The enormous increase in the tannin bearing cells is at once apparent, which, together with a considerable enlargement in the size of the cells indicates a greatly increased tannin content. The particular portion shows by no means a maximum of tannin cells, as can be seen by an examination of fig. 1. Running across the section is one of the considerably broadened multiseriate medullary rays, consisting of comparatively large cells; on either side of the ray are the non-tan bearing cells of the bast fibre groups.

A strip of bark was removed from the butt to the top of a tree about 25′ in height, and a series of six sections cut at regular intervals. The bark samples were given the preliminary treatment with a concentrated aqueous solution of potassium bichromate. An examination of the sections shows clearly that the amount of tannin is highest in the bark near the base of the trunk. Commencing at the bottom of the tree we have:—

Section 1. Thickness of bark 5 mms. Inner portion of 0·9 mm. in width containing comparatively little tannin; outer portion contains a large number of tannin bearing cells.

Section 2. Thickness of bark 4 mms. Inner portion 0·6 mm. in thickness containing little tannin.

Section 3. Thickness of bark 4 mms. Tannin more evenly distributed through secondary phloem.

Section 4. Thickness of bark 2·40 mms. Very little tannin in inner portion of 0·9 mm.

Section 5. Thickness of bark 2·40 mms. Tannin comparatively evenly distributed in secondary phloem, but number of tan bearing cells fewer than in 1 and 2.

Section 6. Thickness of bark 1·9 mms. Comparatively little tannin in inner 0·6 mm. Much greater concentration outside this limit.

In all the above sections the greater concentration is found in the cells of the medullary rays where they broaden out, especially in the cells just within the sclerenchymatous sheath corresponding to the pericycle, and in the cells of the primary and secondary cortex, all these being filled with a dark brown precipitate. In many of the cells the contents appear vacuolated; in many cases starch grains are present. The cell walls are scarcely stained, a decided difference from what obtains in the spent bark.

The Melbourne Board of Enquiry (1892) states that the best months for stripping the bark are September, October, November, and December, and also that while the bark strips easily after rain the quality is inferior. Ewart (1912) states that the best time for stripping is the spring or early summer when the sap is rising, since at that time not only does the bark come off more easily, but it is in a better condition for tanning. We are in accord with the statement that spring is undoubtedly the best time for stripping, more particularly on account of the fact that the removal of bark is much easier at that time. This is evidently due to the increased growth of new cells from the cambial layer, which being thin walled are therefore more readily separated. A similar explanation can apparently be given to the fact that the bark is more easily stripped after rain. As far as our investigation has gone there is no evidence to show that the quality of the tannins varies during the different seasons of the year, or after a wet period, except where large increase in new growth would augment the non-tans and insolubles, and thereby increase the risk of fermentation in the extraction vats and tan liquors. This increase in the other constituents might therefore lower the percentage of tannin in the bark although actually a slight increase in the total quantity of tannin may occur. So far we have not obtained any direct evidence that the percentage of tannin varies at different times of the year.

Under normal conditions the amount of tannin in the bark of the tree is proportional to its age. This does not mean that old trees necessarily contain more, or a greater percentage of tannin than young trees, since the amount of fibre present is a factor, and thickness is usually more important than age in its influence on the tannin content. The lack of tannin in the freshly formed cells of the inner bark has been pointed out. (Plate XX, fig. 1). It is evident that the amount of tannin present bears a direct relationship to the age of the cells, since those nearest the cambium contain comparatively little tannin when compared with those nearer the outer cortex. If then it is correct that the percentage of tannin in the bark increases as the percentage of young cells in the bark decreases, then one would expect to find the greatest percentage of tannin at the end of a period of minimum growth, which would normally correspond to the end of the winter months, and therefore this should be the time to strip the bark to obtain the highest yield of tannin. Probably the maximum increase in thickness occurs in the spring and summer whilst during the autumn and winter there is a greater increase in the tannin production. The evidence obtained microscopically as to the distribution was confirmed by the analysis of two samples of bark which were taken and the outer ross removed. Each was then split parallel to the surface into two equal halves, and analysed with the following results:

	Young Tissue.		Old Tissue.	
No. of bark	1	2	3	4
Tannin	17·92	17·02	27·11	29·24
Non-tannin	10·06	12·43	7·89	10·53
Insoluble	63·87	64·15	55·8	53·51
Water	8·15	6·4	9·2	6·72
	100·00	100·00	100·00	100·00 .

It will be noted from the above figures that the older tissues contain the greater amount of tannin whereas the younger cells contain a higher percentage of soluble non-tans. This to a certain extent is similar to results obtained when analysing samples of bark taken from different parts of the tree; the bark at the butt with a maximum of old cells containing more tannin than the bark at the top of the tree, which contains a larger percentage of younger cells. These results seem to point to the fact that the new tannin-bearing cells contain certain substances that are not tannins but apparently change to tannins as the age of the cell increases.

Williams (1915) states that "the percentage of tannins in the thicker portions of the bark felled in winter is appreciably higher in most cases than in the case of bark of corresponding thickness felled in summer. It appears as if there is a greater proportion of tannin in the lower portion of the tree during the winter months and this is what one might expect seeing that the sap is usually concentrated more or less towards the base of the tree in the autumn and winter months." If this is correct one would expect to find the tannin in a plastic condition near the cambium whereas the concentration evidently reaches a maximum furthest from the actively conductive tissues of the secondary phloem.

It seems probable that there is little alteration in its position once the tannin is elaborated. An attempt made to prove that the parent bodies of the tannins are found in the soluble non-tans was not successful. Wilson (1916) states that the soluble non-tans after heating changed colour, with the production of tannin. The wattle bark extracts we have examined also changed to a red colour upon heating, but no indication of tannin was found in this solution with the gelatine test.

In order to determine the amount of moisture in the bark as it occurs on the tree, samples were weighed immediately after stripping. When dry, after a long exposure to air, they were again weighed, and the moisture and tannin contents determined by the usual method. The results were as follows:—

	1	2	3	4	5
Tannin	17·08	17·35	16·15	9·43	14·37%
Non-tannin	4·29	4·53	4·62	4·51	5·96%
Insolubles	22·34	24·55	24·78	28·09	27·05%
Water	56·29	53·57	54·45	57·97	52·62%

From the above figures it is possible to obtain some idea of the concentration of the solution of the tannins and total solubles in the cell, *e.g.*, if all the water present acts as a solvent for this material we find that:—

	(1)	(2)	(3)	(4)	(5)
Concentration of total solubles	=27·5	29·0	27·6	19·4	27·8%
,, tannin	=22·0	23·0	21·4	13·1	19·7%

This assumption however is obviously incorrect. If we assume that the percentage of moisture in the cell walls is 50,[1] the concentration of the solubles is largely increased. Allowing then 50% of water in the insolubles, we find that the concentration of the total solubles and tannins are as follows:—

	(1)	(2)	(3)	(4)	(5)
Concentration of total solubles	=38·6	43·0	41·1	31·8	44·3%
,, tannin	=30·9	34·1	32·0	21·5	31·3%

These figures are very probably by no means the highest that can be obtained, but they are sufficient to show that a very high concentration is reached, if the tannin is wholly in solution in the cell sap. Under ordinary conditions such a solution would be extremely viscous.

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[1] This is a very conservative figure. Pfeffer *l.c.*, estimates that the percentage of moisture in the cellulose cell walls is 70 – 90; in the lignified walls, 50%. In the Acacia bark only a proportion of the cell walls are lignified, and moreover the amount of water in the other insolubles present, *e.g.* starch, albuminoids, etc., would be considerably in excess of this amount.

After stripping, the bark is air dried, the moisture content being reduced from about 55 per cent. on the wet weight to normally about 10 per cent., by exposure to ordinary atmospheric conditions. The moisture is probably present in the bark in three ways, (1) as free water in the cells, (2) as water present in combination with the cell contents, and (3) as moisture absorbed by the cell walls. In the air dried bark it is probable that the moisture is distributed between the cell walls and the cell contents, which in this case are principally tannin. The theory has been advanced that the contraction which occurs in drying, and the subsequent crushing of the bark, results in small cracks. No evidence has, however, so far been found that the rupture of the cell walls actually takes place, but it is a fact that the bark must be crushed before the majority of the tannin can be extracted. This crushing must however rupture certain of the cells, and by reducing the size of the particles of bark, would allow the readier penetration of water and hence give rise to a more efficient extraction.

An interesting feature connected with this work is found when extraction results with Adelaide and South African barks are compared. The former has always the appearance of a bark which has been stored, and thoroughly dried, since it is distinctly red—a sure sign of exposure. The South African bark is pale in comparison with that of Adelaide, and certainly does not appear to have been cut for any length of time. The Adelaide bark appears to give up its tannin more readily than the South African bark. Some Australian tanners believe that the longer the period that is allowed to elapse after the time of stripping, the easier is the extraction of the tannin from the bark. [Coombs, 1919.]

Small pieces of the fresh bark were placed in potassium bichromate solution. Sections were also cut from fresh untreated bark, transferred to water, and then into a saturated aqueous solution of bichromate. It was found that the longer the preliminary treatment with water, the less pronounced was the reaction given by the potassium bichromate. The rapidity of the diffusion of the tannin from the cells is indicated by the fact that even after as short a period as five seconds in water, an appreciable difference could be found when compared with sections from material which had first been treated with the bichromate solution. All sections were of uniform thickness. After five seconds the brown precipitate was most pronounced in the medullary rays, and also in the tannin bearing phloem parenchyma cells. After ten seconds a still further reduction in the intensity of the colouration was observed, similarly after fifteen seconds. After six minutes the contents of the medullary rays, and also of isolated cells in the cortex, were stained. After thirty-six minutes the medullary rays were still distinct and also certain cells of the secondary cortex and phloem. After five hours a few cells of the the medullary rays were affected but there was comparatively little difference between this and the thirty-six minutes exposure. A section which after four hours in cold water was boiled and then transferred to bichromate showed no reaction in the medullary ray cells, but certain of the cells in the secondary phloem became somewhat yellowish, and in places the cell walls were stained a light brown. Similar results were obtained by boiling sections cut from fresh bark.

From these results it seems evident that the greater percentage of the tannin in the fresh bark is readily soluble in cold water, the rapidity of solution depending on the amount of surface exposed. There does not appear to be any clear evidence to support the prevalent idea that the solubility of the tannin increases with the length of time bark is kept after stripping, but further work remains to be done on this subject.

A portion of the spent bark after extraction of the tannin under ordinary commercial conditions was examined, after a further treatment with alcohol and chloroform, by means of paraffin sections. Many of the cells of the outer expanded portion of the medullary rays were found to be wholly or partially filled with almost clear, colourless, amorphous, slightly granular contents, sometimes showing signs of striation. Numerous starch grains were present both in these cells and also in those apparently without other contents. In the tissue of the secondary cortex many of the parenchyma cells also possessed contents. The irregular branching groups of collapsed sieve tubes were decidedly coloured, being especially prominent in contrast with the lighter coloured surrounding cells. The most prominent portion of the medullary rays was nearest the cambium, the contents being light brown in colour; further out the cells of the rays were often devoid of contents, at other times containing an amorphous mass. Here also starch grains were numerous.

Similar sections treated with potassium bichromate gave the most pronounced colouration in the collapsed groups of sieve tubes and companion cells, these becoming brown. The more or less striated cell contents of the broad medullary rays, parenchyma, etc., were only slightly stained, and the cell walls were considerably more prominent. The innermost cells of the medullary rays showed a very pronounced colouration, as also obtained in the adjacent parenchyma.

With ferric chloride, the same changes were observed, the collapsed sieve tube areas, especially those near the cambium being stained to a bluish grey, though they show no tannin reaction in fresh bark. It seems evident, therefore, that the tannin is absorbed by the cell walls during the diffusion of the contents in water, The walls of the heavily lignified bast fibre cells showed very little alteration. With iodine solution, the lignified tissues were stained yellow. With chlor-zinc-iodine, the contents of the parenchymatous cells became somewhat violet, the collapsed sieve tube areas, however, were scarcely affected. The probable presence of a cellulose-like body in the parenchymatous cells seems to confirm the conclusion arrived at by Lloyd, *l.c.*, as to the occurrence of an adsorption equilibrium between the tannin and a second body, in certain cases. As already pointed out no evidence was found of any rupturing of the walls of the cells in which the tannin occurs.

It is proposed to make a thorough investigation both chemically and anatomically of the barks of the *Acacia decurrens* group in particular. In the very complete investigation made on the wattle barks (Maiden 1891), over thirty years ago, the Lowenthal method of analysis was used, and the results may differ from those obtained by the modern hide powder method. A close study of the seasonal variation, if any, in the tannin content, by obtaining a series of bark specimens from the same trees will also be made.

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Explanation of Plates.

PLATE XX.

Fig. 1. Transverse section of the bark of *Acacia decurrens* showing the distribution of the tannin after the precipitation with potassium bichromate. The tannin-bearing cells increase in number and size from the cambial zone at the bottom of the figure, towards the outer corky tissues seen at the top. × 14.

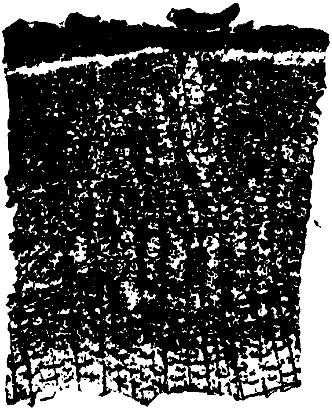


Fig. 1.

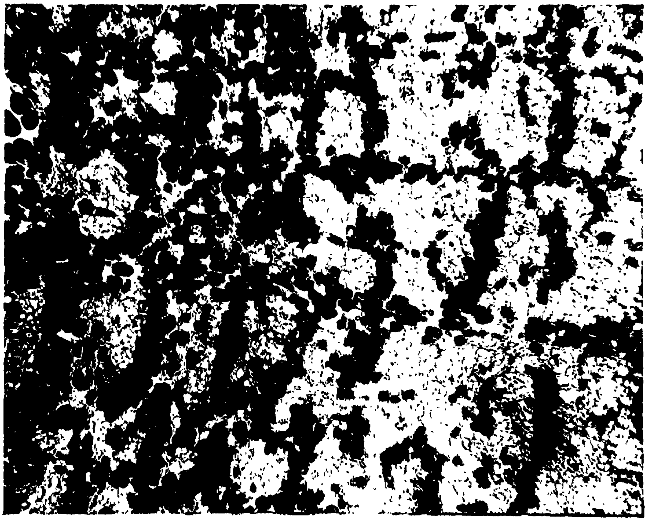


Fig. 2.

Fig. 2. Transverse section of that portion of bark seen in the lower rectangle in Fig. 1. Towards the right hand edge are the newest cells of the secondary phloem, which are practically devoid of tannin, the latter becoming more pronounced in the older cells of the phloem parenchyma. Tannin is also present in the cells of the medullary rays, (running horizontally in the figure) at a very early stage, but the companion cells, sieve tubes and bast fibres show no evidence of it. × 95.

PLATE XXI.

Fig. 3. Transverse section of that portion of bark seen in the upper rectangle in Fig. 1. This section shows the enormous development of tannin-bearing parenchymatous cells in the broader fan-shaped medullary rays, and in the phloem parenchyma. There is no evidence of tannin in the bast fibre zones (seen as groups of small, clear thick walled cells), or in the collapsed sieve tubes and companion cells. × 95.

Fig. 4. Transverse section of the bark of *Acacia decurrens* after removal of the tannin, showing portion of the secondary phloem. The narrow, dark coloured areas represent the collapsed groups of sieve tubes and companion cells. The isolated bast fibre zones are separated by the medullary rays, which are seen as more or less regular bands of cells, and also by the phloem parenchyma cells. × 24.

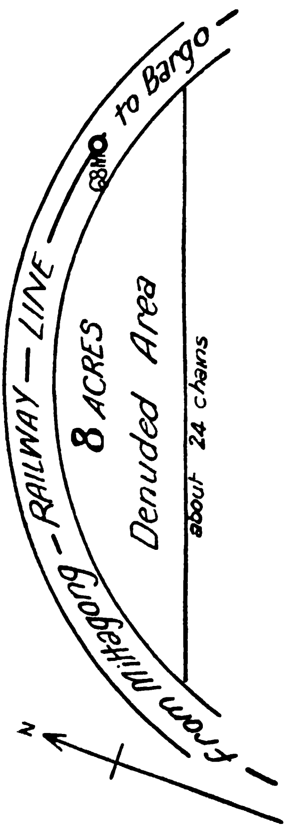
PLANT INVASION OF A DENUDED AREA.

By R. H. Cambage, F.L.S.

With Plate XXII, and Text Figure.

[Read before the Royal Society of N. S. Wales, December 5, 1923.]

When constructing the railway deviation from Picton to Mittagong about five years ago, the Railway Department required a considerable amount of filling where the line crosses a gully at the 68 mile-post near Bargo. In order to obtain material for this filling, an excavation from one to about four feet deep was made over an area of 8 acres which forms the segment of a circle of 18 chains radius, and having a chord of about 24 chains in length. This area, which remains surrounded with virgin forest, was at once securely fenced and made inaccessible to stock, and the only possibility of this denuded enclosure becoming the home of plant-life will be by natural methods, with the possible exception that grasses may be introduced along the railway line from stock trains, and may spread thence on to these bare rocks when they are sufficiently decomposed to receive them. There is a slight slope towards the north from the adjoining bush land, so that seeds may at times be carried on to this area as the



result of heavy rain. Birds, and wind to some extent, will also act as conveyers of seed.

The rock forming the present surface is a friable sandstone containing some shale bands, and is known as Hawkesbury Sandstone of the Triassic period.

I am indebted to Mr. J. C. H. Mingaye for the following partial analysis of a sample of this sandstone rock :—

Silica	78·74	Magnesia	0·29
Alumina*	13·48	Potash	0·97
Ferric Oxide	1·30	Soda	0·19
Ferrous Oxide	0·27	Titanium Dioxide	0·42
Lime	0·34		

* Including any Phosphoric anhydride present.

The annual rainfall in this locality is probably in the vicinity of 35 inches.

As this denuded area and the adjoining forest are likely to remain in their present state for many years, the opportunity is afforded of observing a natural invasion of plant life on an uninviting rocky surface, and an examination every few years should prove instructive.

The following is a record of the plants found growing on this area on the 3rd November, 1923, at about the end of the first five years:—

GRAMINEÆ: *Calamagrostis æmula* Steud., *Danthonia racemosa* R.Br., *Festuca myurus* (naturalised).

HÆMODORACEÆ: *Hæmodorum planifolium* R.Br.

IRIDACEÆ: *Patersonia sericea* R.Br. (Wild Iris).

CASUARINEÆ: *Casuarina suberosa* Ott. and Dietr. (Forest Oak).

PROTEACEÆ: *Petrophila pulchella* R.Br., *Grevillea sphacelata* R.Br., *Banksia spinulosa* Sm.

POLYGONACEÆ: *Rumex acetosella* L., (Sorrel, naturalised).

LEGUMINOSÆ: *Acacia juniperina* Willd., *A. suaveolens* Willd., *A. linifolia* Willd., *A. myrtifolia* Willd., *Mir-*

belia reticulata Sm., *Gompholobium grandiflorum* Sm., *Sphærolobium vimineum* Sm., *Daviesia corymbosa* Sm., *Dillwynia peduncularis* Sieb. (a prostrate form), *D. floribunda* Sm.? (not sufficiently developed for definite determination), *Bossiœa microphylla* Sm.

POLYGALACEÆ : *Comesperma ericinum* DC.

EUPHORBIACEÆ : *Poranthera ericifolia* Rudge.

THYMELÆACEÆ : *Pimelea linifolia* Sm.

MYRTACEÆ : *Eucalyptus eugenioides* Sieb. (Stringybark), *E. hœmastoma* Sm. (Brittle Gum), *E. Sieberiana* F.v.M. (Mountain Ash), *Leptospermum attenuatum* Sm.

UMBELLIFERÆ : *Trachymene linearis* Spreng.

GOODENIACEÆ : *Goodenia hederacea* Sm.

COMPOSITÆ : *Olearia Nernstii* F.v.M., *O. microphylla* Benth., *Hypochœris radiata* L. (Dandelion, naturalised).

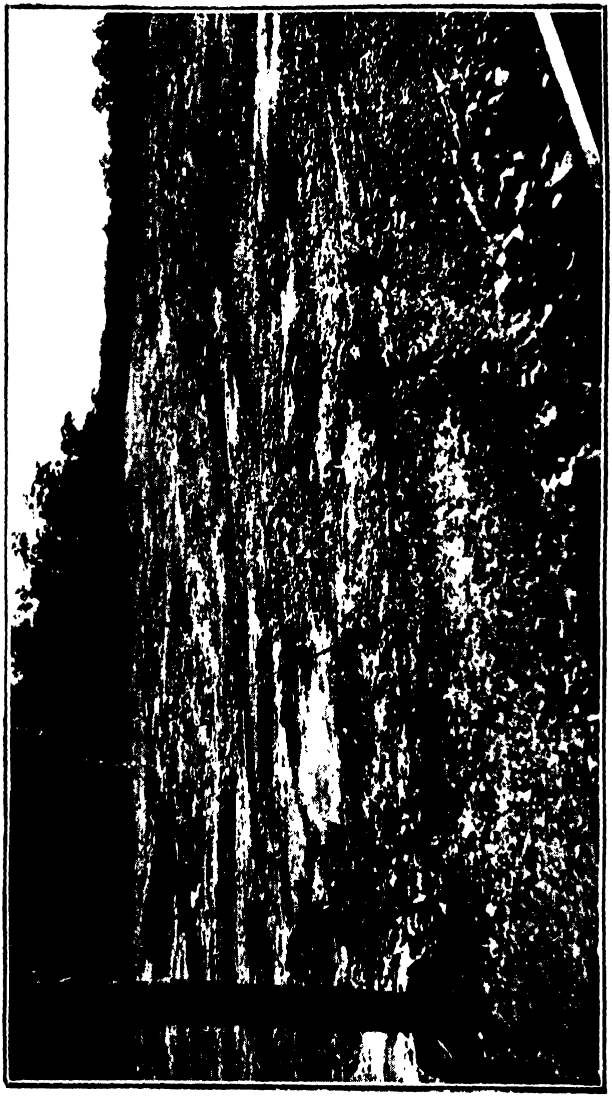
From the above list it may be seen that about thirty-three species have established themselves on this denuded area. Practically the whole of these, as well as many others, were noticed on the adjoining land.

The species most plentifully represented on the invaded surface are:—*Patersonia sericea*, *Rumex acetosella*, and *Daviesia corymbosa*.

Already small accumulations of sand are beginning to form and a miniature sand-dune three to four feet across and about nine inches high, is held in position by a cluster of plants of *Mirbelia reticulata*.

The tallest Eucalyptus is a seedling of *E. Sieberiana*, about one foot high, while a plant of *Acacia linifolia*, about six feet high, is the tallest on the area.

I wish to express my thanks to Mr. J. H. Maiden, F.R.S., for assistance and corroboration in the identification of some of the plants.



Denuded Area at Bargo, showing gradual plant invasion. (Looking Westerly.)

ON THE OCCURRENCE IN NEW SOUTH WALES OF *GIBBERELLA SAUBINETII*, THE ORGANISM CAUSING SCAB OF WHEAT AND OTHER CEREALS.

By H. J. HYNES, B.Sc. Agr.,
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University of Sydney.

[With Plates XXIII - XXVII.]

[*Received February 8th, 1924.*]

Introduction.

Of late years considerable attention has been devoted to certain members of the genus *Fusarium*, a fungus causing foot-rot and head-blight of cereals. In the United States the total annual losses caused by the ravages of *Gibberella Saubinetii* (Mont.) Sacc., are heavy. In 1919,⁽⁵⁾* an epidemic year, the losses in spring and winter wheat amounted to almost 80,000,000 bushels. In Russia the *Fusarium* blight is known to be one of the most destructive of the cereal diseases.

As far as Australia is concerned, there is no record of any very serious damage to cereal crops being caused by any member of the *Fusarium* group. In 1896 McAlpine⁽²⁾ recorded a *Fusarium* "forming salmon-coloured patches on stems of wheat, especially at the nodes, and on ears." Hamblin⁽⁶⁾ in 1921 found the genus *Fusarium* in association with certain foot-rot conditions of wheat but did not investigate the matter further.

In the course of work dealing with *Helminthosporium* and *Ophiobolus* diseases of wheat, numerous tissue-platings have been made from plants showing foot-rot and node-blight conditions. From these platings the genus *Fusarium* has been isolated so frequently that the writer considers that this fungus may be important in producing certain of the cereal foot-rots in New South Wales.

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* Numbers in brackets refer to literature citations.

In January 1922, Mr. W. L. Waterhouse, of the Faculty of Agriculture, Sydney University, collected oat stubble at the Grafton Experiment Farm, N.S.W., which showed a definite foot-rot condition; the main roots of a few of the plants were covered with a thin, whitish, mycelial weft. Associated with this foot-rot condition Mr. Waterhouse found numerous perithecia (Plate XXIII) which he considered to belong to the genus *Gibberella*. From this material a culture was obtained on potato dextrose agar, showing typical *Fusarium* characters. In April of 1923 the perithecial material and *Fusarium* cultures were handed over to the writer for detailed study.

In November of the same year Mr. Waterhouse found that certain plants of crossbred wheat (Canberra × Thew) growing in the Sydney University Experiment Plot were attacked by a *Fusarium*, producing typical head-blight lesions. The studies here reported, however, do not relate to this material.

Morphology of the Fungus.

(A) *Perithecial Stage.*

An examination of perithecia, asci and ascospores taken from the original material clearly demonstrated that the organism belonged to the genus *Gibberella* Sacc. These results are set out hereunder.

Perithecia (Plate XXIII) occur in clusters on nodes, internodes and upper part of roots of oat stubble. These perithecia (Plate XXIV, fig. 1) found free on the surface of the host, are ovoid in shape. They are black in reflected, but dark blue in transmitted light. The peridium in all cases is smooth, occasionally warted, and larger-celled towards the beak end of the perithecium. A few of the perithecia show projections of cell-groups near the apical end.

The asci (Plate XXIV, fig. 2) are oblong-lanceolate in shape; intermixed with them an occasional paraphysis (Plate XXIV, fig. 3) was found.

The ascospores (eight in each ascus) (Plate XXIV, fig. 4) are arranged in one, or irregularly in two rows. In shape they are fusiform, curved slightly and taper toward the ends. In mass they are very faintly ochreous, almost hyaline.

From measurements made of 50 perithecia, 100 asci and 100 ascospores taken from the original material, the following distributions of lengths and breadths were secured:

TABLE I.—*Measurements of 50 Perithecia.*

Range of Length in Microns.	Number of Perithecia.	Range of Breadth in Microns.	Number of Perithecia.
111 - 140	2	111 - 140	5
141 - 170	2	141 - 170	11
171 - 200	14	171 - 200	16
201 - 230	9	201 - 230	11
231 - 260	19	231 - 260	7
261 - 290	4		
Range of Length	116 – 266μ	Range of Breadth	116 – 249μ
Mean	216μ	Mean	189μ

TABLE II.—*Measurements of 100 Asci.*

Range of Length in Microns.	Number of Asci.	Range of Breadth in Microns.	Number of Asci.
30 - 40	6	4 - 6	12
41 - 50	30	6 - 8	57
51 - 60	34	8 - 10	17
61 - 70	17	10 - 12	14
71 - 80	13		
Range of Length	33 - 78μ	Range of Breadth	4 - 11μ
Mean	55μ	Mean	8μ

TABLE III.—*Measurements of 100 Ascospores.*

Range of Length in Microns.	Number of Spores.	Range of Breadth in Microns.	Number of Spores.
0–Septate			
18 - 22	3	3 - 4	3
1–Septate			
18 - 22	2	3 - 4	2
2–Septate			
13 - 21	4	3 - 5	4
3–Septate			
15 - 33	90	3 - 6	90
5–Septate			
29 - 30	1	4 - 5	1
Range of Length	13 – 33μ	Range of Breadth	3 – 6μ
Mean	21μ	Mean	4μ

Wollenweber⁽³⁾ gives measurements for the perithecial stage of *Gibberella Saubinetii* (Mont.) Sacc., as follows:—Perithecia 150 – 250 by 100 – 250μ. Ascopores 20 – 30 by 3·75 – 4·25μ (largely 3-Septate).

(B) *Conidial Stage.*

Cultures obtained from the original perithecial material gave colony growth and spore characters typical of *Fusarium*. The conidia (Plate XXIV, fig. 5) are long and slender, ochreous in mass. No chlamydospores or microconidia were found. The following are the measurements made of 100 conidia taken from a culture of the fungus on sterilized wheat shoots kept at room temperature for four months.

Wollenweber⁽³⁾ gives measurements of conidia of *Gibberella Saubinetii* (Mont.) Sacc., as varying from 30 to 60μ in length and from 4·75 to 5·5μ in breadth; 3- to 5-Septate.

Atanasoff⁽⁴⁾ in connection with the same organism states: "conidia typically, sometimes up to 100 per cent. 5-Septate, 45 to 65μ by 4·2 to 5·5μ; 3-Septate, 35 to 45μ by 5 to 5·5μ; seldom 4-Septate; rarely 6-, 7-, or more septate, 60 to 75μ by 4 to 5μ."

TABLE IV.—*Measurements of 100 Conidia.*

Range of Length in Microns.	Number of Conidia.		Range of Breadth in Microns.	Number of Conidia.
28 – 32	2	0–Septate	3 – 4	2
30 – 31	1	1–Septate	3 – 4	1
36 – 40	3	2–Septate	3 – 5	3
23 – 45	33	3–Septate	3 – 5	33
27 – 45	26	4–Septate	3 – 5	26
36 – 54	34	5–Septate	3 – 5	34
43 – 44	1	6–Septate	3 – 4	1
Range of Length	23 – 54μ		Range of Breadth	3 – 5μ
Mean	39μ		Mean	5μ

From a comparison of these morphological characters of the perfect and imperfect stages of the Australian *Gibberella* with those of *Gibberella Saubinetii* (Mont.) Sacc., given by Wollenweber(3) and Atanasoff(4), the writer concludes that the two organisms under comparison are similar.

Cooke(1) in his "Handbook of Australian Fungi" refers to *Gibberella Saubinetii* found on *herb* stems in Victoria and Tasmania. His account is far from complete.

Cultural Characters of the Fungus.

Preliminary studies of the cultural characteristics of the the local form of *Gibberella Saubinetii* have been made on potato dextrose agar, potato mush agar, potato plugs, rice, wheat heads and lucerne shoots. Using a similar series of media, comparisons have been made with a strain (Strain No. 259) of the same fungus secured by Mr. W. L. Waterhouse from Dr. L. R. Jones of Wisconsin, U.S.A.

The comparative studies made with the agar media were carried out in petri dishes under strictly comparable conditions.

Rice tubes were prepared by placing polished rice grains to a depth of 1 cm. in test tubes, adding enough water to stand 1 cm. above this and then sterilizing in the autoclave. About two weeks from inoculation was found to be the best time for examining these rice cultures. The potato plugs, wheat heads, and lucerne stems were prepared in the usual way by placing them on a small pad of moist cotton wool in test tubes and then autoclaving; in the case of the potato plugs, water was added to the tubes without any cotton wool.

After inoculation, the petri plates and test tubes were incubated at a temperature of 25 – 27° C.; all work was done in duplicate. A brief summary of the outstanding differences between the two strains cultured is given as follows:—

(a) *Potato dextrose agar (P.D.A.) and potato mush agar (P.M.A.)*

The accompanying table (Table V) shows the pronounced differences between the two strains cultured on the same and on different media. P.D.A. is useful for the development of such characters as aerial mycelium, colony colour and discoloration of the medium (Plate XXV, figs. 1 and 2); P.M.A. is valuable for the rapid production of perithecia in the Wisconsin form (Plate XXV, figs. 3 – 5).

(b) *Rice in Test Tubes.*—The Australian form (No. 1) after growing on rice for 14 days, gave white mycelial growth together with a light yellowish discoloration (canary colour) of the rice grains. The Wisconsin form (No. 2) was markedly different. It gave little, if any, mycelial growth and a characteristic orange-yellow discoloration of the grains.

Table V.—*Cultural characteristics of two strains of Gibberella Saubinetii grown on potato dextrose agar and potato mush agar under the same conditions.*

Strain.	Colony diameter in centimetres.				Character of Growth.		Colony colour.		Discolouration of medium.	
	P.D.A.		P.M.A.		P.D.A.	P.M.A.	P.D.A.	P.M.A.	P.D.A.	P.M.A.
	4 days	6 days	4 days	6 days						
No. 1 (Australian)	7·8	10	7·5	10	Regular, dense. Aerial mycelium abundant, white and elevated. No perithecia.	Regular, thin. Aerial mycelium not as dense as on P.D.A., elevated. No perithecia.	White	Dull white	Pinkish red, fairly uniformly developed.	Trace of pink colour at edge of colony only.
No. 2 (Wisconsin)	7·6	10	7·5	10	Regular, dense. Aerial mycelium scanty, flat, dull white or yellowish pink in parts, more pronounced towards edge of colony. Perithecia form after 13 days.	Regular, thin. Aerial mycelium scanty, loose, flat and white. Perithecia form after 7 days.	Deep red	Dull white	Red, more pronounced in bands radiating from the centre of colony.	Trace of pink colour in parts.

(c) *Potato Plugs.*—Form No. 1 gave a large development of white aerial mycelium completely surrounding the plug. In Form No. 2 the aerial mycelium was not nearly as abundant and was greyish-pink in colour. Another feature of note was the dense, brownish-black growth occurring where the plugs came in contact with the glass; this was not the case with the Australian strain.

(d) *Sterilized Wheat Heads and Lucerne Stems.*—After 14 days Form No. 1 gave abundant growth of white aerial mycelium, tinged yellowish-pink where head or stem came in contact with glass. Form No. 2 produced scanty aerial mycelium, coloured pink; the formation of a pellicle (pinkish-red in colour) over the surface of the water in the tubes was also characteristic of the Wisconsin form. Perithecial formation in Form No. 2 was noted on both the wheat heads and lucerne stems. The latter is a very favourable medium for this purpose, the perithecia forming 6 days after inoculation at 25 – 27° C.

During the past six months numerous attempts have been made to induce perithecial formation in the local strain of *G. Saubinetii.* To date these have been unsuccessful. The methods suggested by Atanasoff(4) have been tried. Starvation methods have proved fruitless. Although in some cases sclerotia were formed, so far no perithecia have been obtained. These results are in striking contrast with those obtained with the Wisconsin form which develops perithecia readily. The absence of perithecial formation is one of the outstanding features of the Australian strain.

Pathogenicity of the Fungus.

The parasitic nature of the fungus was proved by three methods:—(1) The first method used was that suggested by Atanasoff(4). Heads of Federation wheat at blossoming time were sprayed with distilled water from an atomiser and then inoculated with agar cultures of the organism by means of a sterile flat needle. As this test was conducted during warm, dry weather, it was essential that a moist atmosphere should be maintained in order to insure infection. This was done by placing a bundle of moist cotton wool round the stems of a group of heads which had been inoculated; a piece of cheese cloth, wrapped round the cotton wool, was then led down into a conical flask of water in order to keep the wool moist. The heads were then covered with a glassine paper bag, the open end of which was tied just below the bundle of cotton wool. On removing the bags 6 days from time of inoculation, the heads showed typical *Fusarium*-blight lesions (Plate XXVII, fig. 2). These took the form of water-soaked patches on the glumes with a definite brown zone round the infected area; these areas, which were about 3 mm. wide, were covered by a pinkish-white mat of mycelium. All heads were then removed and placed in a moist situation under a tree. This was done with a view of inducing the formation of perithecia.

(2) This test consisted in first autoclaving a pot of loamy garden soil which, after cooling, was heavily inoculated with a pure culture of the fungus growing on sterilized wheat grains in Erlenmeyer flasks. Grain of Hard Federation wheat, previously surface-sterilized in mercuric chloride, was then sown in the inoculated soil. Within 12 to 14 days after sowing the grain there were very definite indications of infection. All seedlings showed stunting; some were irregularly developed; some showed large tobacco-coloured lesions on the coleoptile with apparently no very severe damage to the plants, whilst yet others failed to push out the first leaf, but soon died. (Plate XXVI, fig. 2). Following this same method the fungus was also proved to be parasitic upon Algerian oats, Cape barley and Black Winter rye.

(3) In the third method, four 4 inch pots containing healthy seedlings of Federation wheat, Algerian oats, Cape barley and Black Winter rye were used. These seedlings, particularly the bases, were moistened with distilled water from an atomiser and then inoculated by placing pieces of vigorously growing cultures of the fungus on agar in contact with the coleoptile at soil level with a sterile needle. All pots were then kept in a saturated atmosphere for forty-eight hours. Plants examined seven days after inoculation showed definite infection in all four cereals, the coleoptile being of a pronounced tan colour in the case of wheat, barley and rye; in the oat seedlings, however, the tan colour was not so well developed, a feature also observed in connection with the oats in test No. 2.

From the plant parts showing infection in each of the above tests, the *Fusarium* was reisolated in pure culture. It is concluded, then, that the local form of *Gibberella Saubinetii* (Mont.) Sacc., under favourable conditions for infection is pathogenic on heads of Federation wheat and is also capable of producing seedling-blight in Federation and Hard Federation wheat, Algerian oats, Cape barley, and Black Winter rye.

* * * *

In conclusion the writer desires to acknowledge his indebtedness to Mr. W. L. Waterhouse for supplying material and cultures and for the very helpful advice and criticism given during the course of the investigation.

Summary.

1. Oat stubble, bearing perithecia, was obtained at Grafton, N. S. Wales, in January 1922.
2. Morphological studies of the perfect and imperfect stages of the fungus show that the organism is *Gibberella Saubinetii* (Mont.) Sacc.

3. There are certain marked cultural differences between this local strain and a pure culture of the fungus obtained from Wisconsin, U.S.A.
4. Greenhouse experiments with the local strain show that it is parasitic upon Federation and Hard Federation wheat, Algerian oats, Cape barley and Black Winter rye.

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3. 1914—Wollenweber, H. W. "Identification of species of *Fusarium* occurring on the sweet potato, *Ipomoea Batatas*," Jour. Agr. Res. Vol. 2, No. 4, p. 251.
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5. 1921—Johnson, A. G. and Dickson, J. G. "Wheat Scab and its control," U.S.D.A. Farmers' Bull. 1224.
6. 1922—Hamblin, C. O. "Foot-rot of Wheat caused by the fungus *Helminthosporium*." Agr. Gaz. N.S.W., Vol. 33, pt. 1, p. 13.

Explanation of Plates.

Form No. 1 refers to the Australian strain of *Gibberella Saubinetii* (Mont.) Sacc., Form No. 2 to a Wisconsin strain (No. 259, L. R. Jones) of the same species.

Figures in Plate XXIV were drawn with the camera lucida under a Leitz $\frac{1}{12}$ inch oil-immersion objective and No. 12 ocular, except fig. 1, which was drawn under a Zeiss 15 mm. objective and No. 12 ocular. All petri dishes were incubated at 25 – 27° C.

Plate XXIII.

1. Oat stubble showing foot-rot condition and abundant perithecia. Australian material.
2. Enlarged view of part of culm showing perithecia.

Plate XXIV.

Showing perfect and imperfect stages of Form No. 1. 1. Perithecia × 133; 2. Asci × 1333; 3. Paraphysis × 1333; 4. Ascospores 1333; 5. Conidia × 1333. Figs. 1 – 4 drawn from original material, fig. 5 from culture on sterilized wheat shoots.*

Plate XXV.

1. Form No. 1 on potato dextrose agar after 10 days.
2. Form No. 2 „ „ „ 8 days.
3. Form No. 1 on potato mush agar after 8 days.
4. Form No. 2 „ „ „ 4 weeks; note the perithecia.
5. The two forms on potato mush agar after 4 weeks; note the perithecial formation in Form No. 2 on right half of dish.

Plate XXVI.

1. Control plants of Hard Federation wheat, 13 days old.
2. Plants of Hard Federation wheat showing seedling-blight, 13 days after sowing in soil inoculated with Form No. 1.

Plate XXVII.

1. Control heads of Federation wheat.
2. Heads of Federation wheat inoculated with Form No. 1; note lesions on the glumes.

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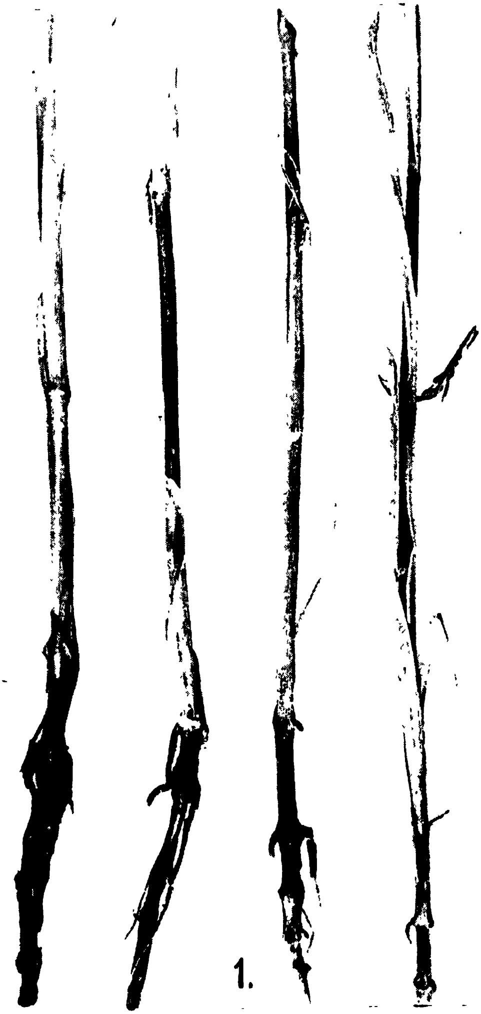
* Ready acknowledgment is made of assistance given in the photographic work by Messrs. H. G. Gooch and W. J. Reay

Journal Royal Society of N.S.W., Vol. LVII, 1923. **Plate XXIII.**



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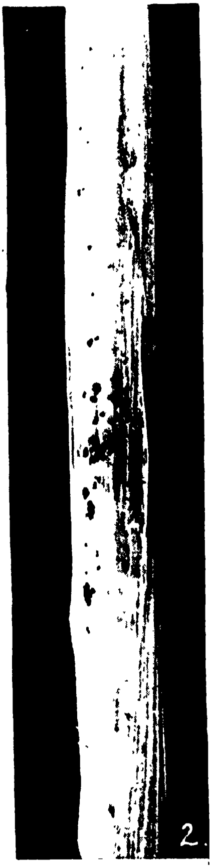

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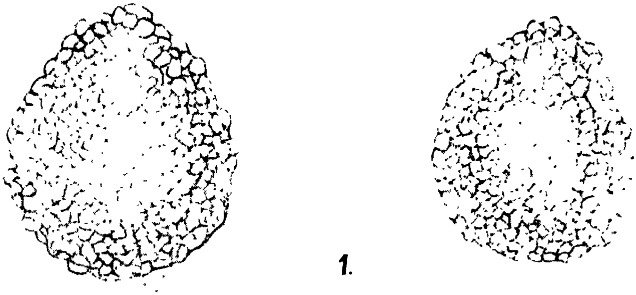

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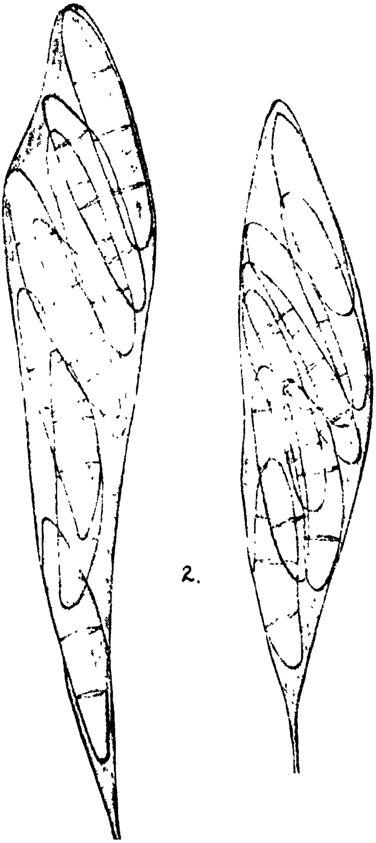

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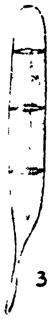

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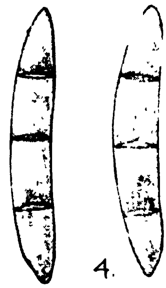

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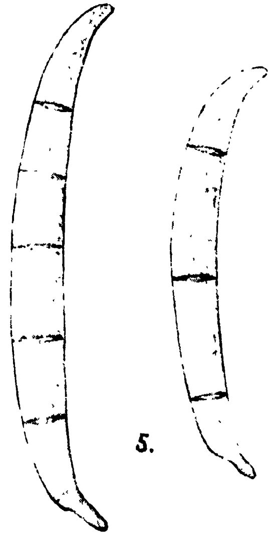

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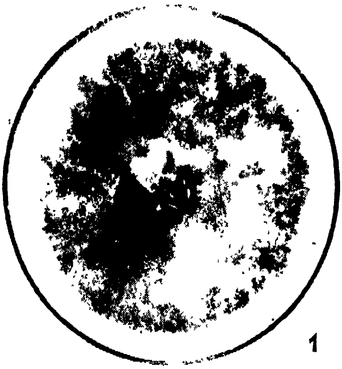

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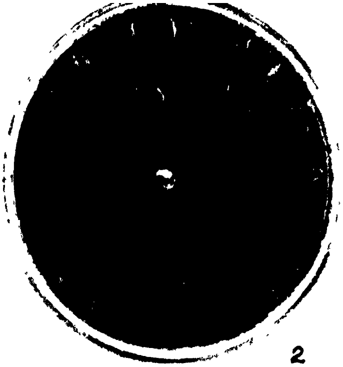

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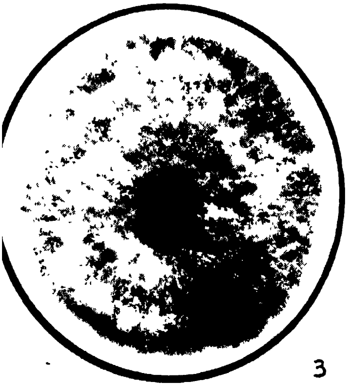

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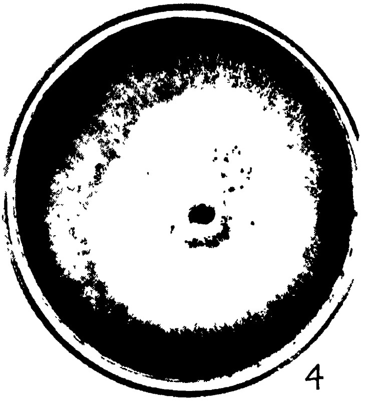

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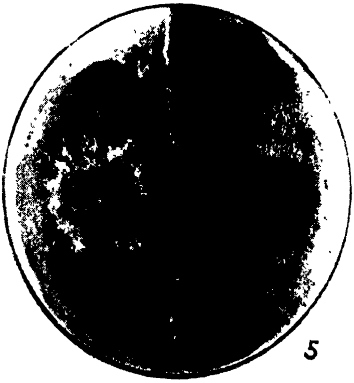

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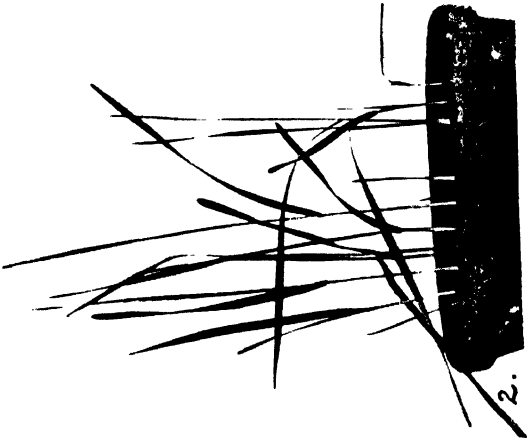
Journal Royal Society of N.S.W., Vol. LVII., 1923. *Plate XXVI.*



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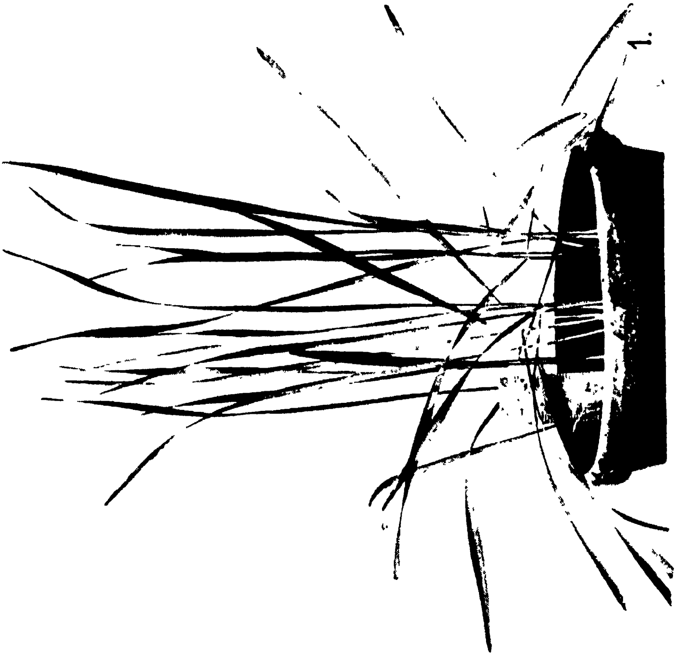

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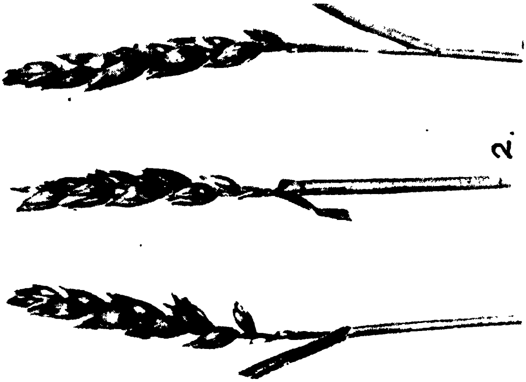

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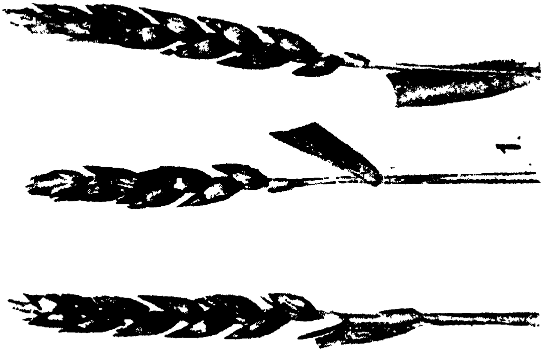

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ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

MAY 2ND, 1923.

The Annual Meeting, being the four hundred and thirty-sixth General Monthly Meeting of the Society, was held at the Society's House, 5 Elizabeth Street, Sydney, at 8 p.m.

Mr. C. A. Sussmilch, President in the Chair.

Fifty-eight members and two visitors were present.

The minutes of the General Monthly Meeting of the 6th of December, 1922, were read and confirmed.

The Certificates of nine candidates for admission as ordinary members were read for the first time.

Messrs. A. D. Ollé and R. W. Challinor were appointed Scrutineers, and Mr. E. C. Andrews deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society:—Jack Keith Murray.

Professor J. T. Wilson was elected an honorary member of the Society.

The President tendered the congratulations of the Society to Professor O. U. Vonwiller on his appointment to the Chair of Physics in the University of Sydney.

It was announced that the following members had died during the recess:—Mr. Albert Bond, Mr. W. E. Kemp and the Honourable J. T. Walker.

Letters were read from Mrs. J. T. Walker and the family of the late Mr. Dugald Thomson expressing thanks for the Society's sympathy in their recent bereavements.

The Annual Financial Statement for the year ended 31st March, 1923, was submitted to members, and on the motion of Professor H. G. Chapman, seconded by Mr. R. T. Baker, was unanimously adopted:—

GENERAL ACCOUNT.

RECEIPTS.

				£	s.	d.	£	s.	d.
To Revenue—									
Subscriptions				699	6	0			
„ Rents—									
Offices	£426	16	2						
Hall and Library	160	15	6						
				587	11	8			
„ Sundry Receipts				14	3	3			
„ Government Subsidy for 1922...				399	19	10			
							1701	0	9
„ Clarke Memorial Fund—									
Loan to General Fund							849	0	2
„ Donations to cost of alterations							129	11	0
„ Building Loan Fund—									
Balances in Savings Bank transferred ...							250	0	0
„ Balance—Union Bank of Australia Ltd.—									
Overdrawn Account, Head Office				3826	8	7			
Less:—Petty Cash on hand				6	17	5			
							3819	11	2
							£6749	3	1

PAYMENTS.

	£	s.	d.	£	s.	d.	£	s.	d.
By Balance as 31st March, 1922 ...							2066	0	3
„ Administrative Expenses—									
„ Salaries and Wages—									
Office Salary & Accountancy Fees	243	15	0						
Assistant Librarian	48	0	0						
Caretaker...	248	18	2						
				540	13	2			
„ Printing, Stationery, Advertising, Stamps, etc.—									
Stamps and Telegrams... ...	40	4	0						
Office Sundries, Stationery etc.	4	13	5						
Advertising	13	1	1						
Printing	65	15	9						
				123	14	3			
Carried forward				664	7	5			

PAYMENTS—*continued*	£	s.	d.	£	s.	d.	£	s.	d.
Brought forward ...				664	7	5			
By Rates, Taxes and Services—									
Electric Light	71	10	10						
Gas	10	1	6						
Insurance...	33	13	9						
Rates	158	2	11						
Telephone...	15	1	7						
				288	10	7			
,, Printing and Publishing Society's Volume—									
Printing, etc.	240	10	3						
Bookbinding	41	13	4						
				282	3	7			
,, Library—									
Books and Periodicals... ...	50	18	5						
Bookbinding	95	1	9						
				146	0	2			
,, Sundry Expenses—									
Repairs	91	14	9						
Lantern Operator	22	10	6						
Bank Charges	0	9	2						
Sundries	26	7	1						
Chairs and Matting	63	11	8						
Legal Expenses	17	5	6						
				221	18	8			
Interest—									
Union Bank of Australia Ltd.	209	5	6						
Clarke Memorial Fund ...	39	9	5						
				248	14	11			
							1851	15	4
,, Building Loan Fund—									
Repayment of Loan							100	14	0
,, Alteration to Premises							2730	13	6
							£6749	3	1

CLARKE MEMORIAL FUND.

BALANCE SHEET, 31ST MARCH, 1923.

LIABILITIES.	£	s.	d.	£	s.	d.	£	s.	d.
Accumulation Fund—									
Balance as at 31st March, 1922 ...				811	7	0			
Less: Loss on Realisation of War Loan Bonds				32	0	0			
				779	7	0			
Additions during the year—									
Interest, Government Savings Bank	10	3	9						
,, Commonwealth War Loan	20	0	0						
,, General Fund	39	9	5	69	13	2	849	0	2
							£849	0	2

ASSETS.	£	s.	d.
Loan to General Fund	849	0	2
	£849	0	2

STATEMENT OF RECEIPTS AND PAYMENTS, 31ST MARCH, 1923.

RECEIPTS.	£	s.	d.	£	s.	d.
To Realisation of War Loan Bond				768	0	0
„ Government Savings Bank				21	10	9
„ Interest War Loan Bonds				20	0	0
„ Interest Loan to General Fund				39	9	5
				£849	0	2

PAYMENTS.	£	s.	d.
By Loan to General Fund	849	0	2
	£849	0	2

Compiled from the Books and Accounts of the Royal Society of New South Wales, and certified to be in accordance therewith.

(Sgd.) HENRY G. CHAPMAN, M.D.,
Honorary Treasurer.

(Sgd.) W. PERCIVAL MINELL, F.C.P.A.,
Auditor.

SYDNEY, 24TH APRIL, 1923.

On the motion of Mr. W. Welch, seconded by Mr. R. W. Challinor, Mr. W. P. Minell was duly elected Auditor for the current year.

It was announced that the Council had awarded the Clarke Memorial Medal to Professor Sir Baldwin Spencer, K.C.M.G., M.A., D.Sc., F.R.S.

The President announced that the following Popular Science Lectures would be delivered during the Session:—

June 21—"Some Wonders of the Australian Flora," by R. T. Baker.

July 19—"Historical and Modern Practice of Quarantine," by J. H. L. Cumpston, M.D., D.P.H.

August 16—"Some Industrial Achievements of Organic Chemistry," by Acting-Professor G. Harker, D.Sc.

September 20—"Some Ancient Volcanoes of Australia," by W. R. Browne, D.Sc.

The Annual Report of the Council was read, and on the motion of Mr. R. H. Cambage, seconded by Mr. R. T. Baker was adopted:—

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1922-23.

(1st May to 24th April).

The Council regret to report the loss by death of nine ordinary members. Eight members have resigned and four names were removed from the list of members through non-payment of subscriptions. On the other hand, eighteen ordinary members have been elected during the year. To-day (24th April, 1923) the roll of members stands at 372.

During the Society's year there have been eight monthly meetings, and ten Council meetings.

Four Popular Science Lectures were given, namely:—

June 15—"The Development of Forestry in New South Wales," by R. T. Dalrymple-Hay, L.S.

July 20—"The Races of the World—their Migrations and Status," by Professor T. Griffith Taylor, B.A., D.Sc., B.E.

August 17—"Solar Eclipses—with special reference to the eclipse which will take place in September next," by J. Nangle, O.B.E., F.R.A.S.

September 21—"The Duck-billed Platypus," by Acting-Professor L. Harrison, B.A., B.Sc.

Meetings were held throughout the Session by the Sections of Geology, Agriculture and Industry.

Thirty-three papers were read at the Monthly Meetings and these, with a good number of exhibits, afforded much instruction and interest to members of the Society.

The Council has awarded the Clarke Memorial Medal to Professor Sir Baldwin Spencer, K.C.M.G., F.R.S., D.Sc.

The following members have been honoured during the year:—Mr. E. C. Andrews, elected Honorary Member of the Washington Academy of Sciences. Mr. J. H. Maiden, F.R.S., awarded the Mueller Medal. Mr. H. G. Smith, awarded the David Syme Medal and Prize.

The Annual Dinner took place at The Burlington, 324 George Street, on 27th April, 1922, when we were honoured by the company of His Excellency Sir Walter Davidson, K.C.M.G., and the Presidents of several societies.

On the evening of the 5th August, 1922, the Royal Society, in conjunction with the Sydney University, the Chancellor, Sir William Cullen, being in the chair, entertained Dr. William W. Campbell, Director of the Lick Observatory and other scientists from the United States of America and from New Zealand, who were visiting Australia for the purpose of viewing the Solar Eclipse on the 21st September, 1922.

The donations to the library have been as follows:—40 volumes, 758 parts, 26 reports, and 1 map.

* * * *

The following donations were laid upon the table:—487 parts, 21 volumes, 13 reports, and 1 calendar.

The President, Mr. C. A. Sussmilch, then delivered his address.

There being no other nominations, the President declared the following gentlemen to be officers and Council for the coming year:—

President:

R. H. CAMBAGE, F.L.S.

Vice-Presidents:

Prof. C. E. FAWSITT, D.Sc., Ph.D.
J. NANGLE, O.B.E., F.R.A.S.
E. C. ANDREWS, B.A., F.G.S.
C. A. SUSSMILCH, F.G.S.

Hon. Treasurer:

Prof. H. G. CHAPMAN, M.D.

Hon. Secretaries:

Prof. O. U. VONWILLER, B.Sc.

G. A. WATERHOUSE, B.Sc. B.E., F.E.S.

Members of Council:

C. ANDERSON, M.A., D.Sc.
Prof. Sir EDGEWORTH DAVID, K.B.E., C.M.G., D.S.O., F.R.S., D.Sc.
W. S. DUN.
R. GREIG-SMITH, D.Sc., M.Sc.
CHARLES HEDLEY, F.L.S.
Rev. E. F. PIGOT, S J., B A., M.B.
W. POOLE, M.E., M. Inst. C.E., M.I.M.M. M.I E, Aust. M. Am. M.I.E.
H. G. SMITH, F.C.S.
Prof. J. DOUGLAS STEWART, B.V.Sc., M.R.C.V.S.
Prof. R. D. WATT, M.A., B.Sc.

The out-going President then installed Mr. R. H. Cambage as President for the ensuing year, and the latter briefly returned thanks.

On the motion of Sir Edgeworth David a hearty vote of thanks was accorded to the retiring President for his valuable address.

Mr. C. A. Sussmilch briefly acknowledged the compliment.

JUNE 6TH, 1923.

The four hundred and thirty-seventh General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Forty-seven members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The President drew attention to the Honours conferred by the King upon two of our members, Sir George Knibbs and Sir Hugh R. Denison, and it was decided that the congratulations of the Society be sent to our fellow members who were thus honoured.

The certificates of sixteen candidates for admission as ordinary members were read; nine for the second, and seven for the first time.

Messrs. R. Grant and E. G. Jacobs were appointed Scrutineers, and Mr. H. G. Smith deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—Frederick John Berry, William Faris Blakeley, John Campbell Earl, John Irvine Hunter, Iven Giffard Mackay, Herbert Robert Seddon, Harold Tindale, Frank Whitehouse and Stanley Eric Wilson.

A letter was read from Mrs. W. E. Kemp expressing thanks for the Society's sympathy in her recent bereavement.

The President announced that a Popular Science Lecture entitled:—"Some Wonders of the Australian Flora," would be delivered by Mr. R. T. Baker, on Thursday, 21st June, 1923.

The President drew attention of members to the Pan-Pacific Science Congress to take place in Melbourne and Sydney during August and September of this year.

The following donations were laid upon the table:—56 parts, 2 volumes, and 1 report.

THE FOLLOWING PAPERS WERE READ:

1. "Relationship of the Australian Languages," by Professor A. L. Kroeber (communicated by C. Hedley), which in his absence was read by Professor O. U. Vonwiller. Remarks were made by Professors Griffith Taylor and J. I. Hunter.

2. "Note on the Dilution of Ethylenebromohydrin with Water," by Professor J. Read and G. J. Burrows, which in their absence was read by Professor O. U. Vonwiller.

3. "The Warped Littoral around Sydney," Part I, by Professor T. Griffith Taylor, B.A., D.Sc., B.E. Remarks were made by Professor L. A. Cotton and the President.

4. "The Germicidal Values of the Principal Commercial Eucalyptus Oils and their Pure Constituents, with observations on the value of concentrated disinfectants," by A. R. Penfold, F.C.S. and R. Grant, F.C.S. Remarks were made by Messrs. A. D. Ollé, R. W. Challinor and Professor H. G. Chapman.
5. "*Stypandra glauca*," by Max Henry, M.R.C.V.S., B.V.Sc., and W. L. Hindmarsh, M.R.C.V.S., B.V.Sc. Remarks were made by Professor J. Douglas Stewart.

JULY 4TH, 1923.

The four hundred and thirty-eight General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Thirty-three members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of twelve candidates for admission as ordinary members were read; seven for the second and five for the first time.

Messrs. A. D. Ollé and R. W. Challinor were appointed Scrutineers and Professor C. E. Fawsitt deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—Harold John Hynes, James Roy Kinghorn, Alan Price Lipscomb, Cicero Augustus Reid, Edward Waldemar Timcke, Richard Douglas Toppin and William Wilson Ingram.

The President announced that Mr. R. T. Baker and Mr. H. G. Smith had been elected honorary members of the Pharmaceutical Society of Great Britain, Mr. J. H. Maiden an honorary Fellow of the National Horticultural Society of America, and that Professor T. Griffith Taylor had been awarded the David Livingstone Centenary Gold Medal by the American Geographical Society of America, also that the Council had sent letters of congratulations to these members.

Letters of thanks for congratulations were received and read from Sir George Knibbs, Sir Hugh Denison, Mr. J. H. Maiden and Mr. H. G. Smith.

The President announced that a Popular Science Lecture entitled:—"Historical and Modern Practice of Quarantine" would be delivered by Dr. J. H. L. Cumpston, on Thursday, 19th July, 1923.

The following donations were laid upon the table:—151 parts, 2 volumes, and 3 reports.

THE FOLLOWING PAPERS WERE READ:

1. "Molecular Solution Volumes in Ethyl Alcohol," by G. J. Burrows, B.Sc., and F. Eastwood, B.Sc.
2. "Two additional species of Leptospermum," by Edwin Cheel.
3. "The Essential Oils of *Callistemon lanceolatus* and *C. viminalis*," by A. R. Penfold, F.C.S. Remarks were made by Mr. E. Cheel and the President.

Professor T. Griffith Taylor delivered an interesting lecturette on "Scientific Problems of the Pacific, Part IV, Ethnology. This was the fourth of a series of lecturettes to be delivered by various members on subjects connected with the Pacific.

EXHIBIT:

Mr. A. E. Stephen exhibited a pod of the match box bean *(Entada scandens)*.

AUGUST 1ST, 1923.

The four hundred and thirty-ninth General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Forty-five members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of eight candidates for admission as ordinary members were read; five for the second and three for the first time.

Messrs. J. Powell and W. W. L'Estrange were appointed Scrutineers and Mr. J. Nangle deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—Antonio Baccarini, Kenneth John Blair, Piero Fiaschi, William Butler Gurney and Travis Henry Harrison.

The President announced the death of Mr. James Henderson, F.R.E.S., who was elected a member in 1899, and that a letter of sympathy had been sent to Mrs. Henderson.

A letter was read from Professor Liversidge thanking the Society for greetings sent from members at the Annual Dinner.

The President announced that a Popular Science Lecture entitled:—"Some Industrial Achievements of Organic Chemistry," would be delivered by Acting-Professor G. Harker, D.Sc., on Thursday, 16th August, 1923.

The following donations were laid upon the table:—89 parts, 2 volumes, 5 reports, and 2 maps.

THE FOLLOWING PAPERS WERE READ:

1. "Cancer of the Ear of Sheep," a contribution to the knowledge of chronic irritation as a secondary factor in the causation of cancer in the lower animals, by Sydney Dodd, D.V.Sc., F.R.C.V.S. Remarks were made by Mr. A. B. Hector.

2. "The Estimation of Cineol in Essential Oils by the Cocking Process," by L. S. Cash, B.Sc., and C. E. Fawsitt, D.Sc., Ph.D. Remarks were made by Messrs. H. G. Smith, A. R. Penfold and A. B. Hector.
3. "Investigations by the late C. O. Hamblin into the Helminthosporium Disease of Wheat," by H. J. Hynes, B.Sc. (Agr.)

Professor H. G. Chapman delivered an interesting lecturette on "Scientific Problems of the Pacific, Part V, Hygiene. This was the fifth of a series of lecturettes to be delivered by various members on subjects connected with the Pacific.

EXHIBIT:

Mr. E. Cheel exhibited a series of specimens of Wattles, some of which are supposed to be the offspring of *Acacia dealbata* crossed with *Acacia Baileyana*, and others supposed to be seedlings from *Acacia Baileyana* crossed with *Acacia decurrens*. He suggested that *Acacia irrorata* of Sieber, described in 1826 from specimens collected in the Port Jackson District by Sieber in 1822, was the same as *A. decurrens* var. *pauciglanulosa;* if so, Sieber's name had priority over that of Mueller. Mr. Cheel also suggested that *Acacia adenophora* of Sprengel (1826), collected in the Port Jackson District by Sieber in 1822, was probably distinct from *A. decurrens* Wildd., with which it had been linked as a synonym by Bentham and others. *Acacia Nabonnandi* G. V. Nash, recently described and figured in Addisonia, Vol. 6 (1921) plate 197, which was supposed to be produced by crossing *A. dealbata* and *A. decurrens* cultivated on the littoral of the Mediterranean, appeared to the exhibitor to be not in any way distinct from *Acacia adenophora*, which was common at Carlingford, Wahroonga, and extended to Cabramatta, Hill Top, Cootamundra and Wagga Wagga.

SEPTEMBER 5TH, 1923.

The four hundred and fortieth General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Twenty-three members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of three candidates for admission as ordinary members were read for the second time.

Messrs. R. W. Challinor and F. A. Coombs were appointed Scrutineers, and Dr. R. Greig-Smith deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—George Frederick Birks, Ernest Le Gay Brereton and Herbert Brown.

The President announced the deaths of Judge E. B. Docker and Mr. Alfred Lee.

Letters were read from Miss Docker, Mrs. Henderson and Mrs. Lee expressing thanks for the Society's sympathy in their recent bereavements.

A letter was read from Professor J. T. Wilson expressing his appreciation of the honour which the Society had conferred upon him in electing him an Honorary member.

The President announced that a Popular Science Lecture entitled:—"Some Ancient Volcanoes of Australia," would be delivered by Assistant-Professor W. R. Browne, D.Sc., on Thursday, 20th September, 1923.

The following donations were laid upon the table:—97 parts, 2 volumes, 4 reports, and 1 map.

The President announced that at future meetings arrangements would be made to have reports given of work carried out by different Sections at the Pan-Pacific Science Congress.

THE FOLLOWING PAPERS WERE READ:

1. "Atmospheric Dust and Atmospheric Ionisation," by Edgar H. Booth, B.Sc. Remarks were made by Professor Vonwiller and Mr. A. B. Hector.
2. "Germicidal values of Australian Essential Oils (exclusive of Eucalypts) and their Pure Constituents, together with those for some Essential Oil Isolates and Synthetics," Part I, by A. R. Penfold, F.C.S. and R. Grant, F.C.S. Remarks were made by Messrs. R. W. Challinor and A. B. Hector.
3. "Preliminary Note on the Electrolytic Reduction of Piperitone," by A.R. Penfold, F.C.S. and F.R. Morrison, A.T.C. Remarks were made by Messrs. H. G. Smith, G. I. Hudson, and A. B. Hector.

OCTOBER 3RD, 1923.

The four hundred and forty-first General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Thirty-five members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The President announced the death of Sir Walter Davidson, Vice-Patron, and stated the Council on behalf of members had conveyed to Dame Margaret Davidson a message of sympathy in her very sad bereavement.

The certificates of two candidates for admission as ordinary members were read for the first time.

The following donations were laid upon the table:—1 volume, 155 parts, 5 reports, and 1 map.

THE FOLLOWING PAPERS WERE READ:

1. "Secretory Epidermal Cells of certain Eucalypts and Angophoras," by M. B. Welch, B.Sc.
2. "Note on the effect of Temperature on Borers attacking seasoned and unseasoned Timber" (with special reference to the Furniture Beetle), by M. B. Welch, B.Sc. Remarks were made by Messrs. R. Grant, A. D. Ollé, R. T. Baker J. E. Bishop, and G. Hooper.
3. "Note on the occurrence of Double Embryos in Wheat Grains," by W. L. Waterhouse, B.Sc.

EXHIBIT:

Mr. C. W. Mann exhibited an apparatus illustrating the Neutrodyne principle for Wireless Reception.

Professor R. D. Watt delivered an interesting lecturette on the work done by the Section of Agriculture during the Pan-Pacific Science Congress.

NOVEMBER 7TH, 1923.

The four hundred and forty-second General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Thirty-nine members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The President announced the death of Dr. J. R. L. Dixon who was elected a member in 1916.

A letter was read from Dame Margaret Davidson expressing thanks for the Society's sympathy in her recent bereavement.

The certificates of two candidates for admission as ordinary members were read for the second time.

Messrs. R. Grant and F. A. Coombs were appointed Scrutineers, and Dr. C. Anderson deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—Lindsay Duncan Cameron and David Thomas.

The following donations were laid upon the table:—5 volumes, 125 parts, 1 report, 1 catalogue, and 2 maps.

THE FOLLOWING PAPERS WERE READ:

1. "Method of computing the True Anomaly in an Elliptical Orbit from values of the Mean Anomaly," by C. J. Merfield, F.R.A.S., communicated by Mr. J. Nangle, O.B.E., F.R.A.S.
2. "The Essential Oil of *Darwinia grandiflora* and the presence of a new Acetic Acid Ester," by A. R. Penfold, F.C.S. Remarks were made by Messrs. H. G. Smith and E. Cheel.
3. "Notes on the Bacteriology, Titratable Acidity and H-ion concentration of some Creams," by J. K. Murray, B.A., B.Sc., and V. Weston, H.D.D., which in their absence was read by Mr. G. Wright.
4. "The Distribution of the Active Deposit of Radium in Helium and Argon in an Electric Field," by G. H. Briggs, B.Sc. Remarks were made by Prof. Vonwiller.

Mr. C. Hedley delivered an interesting lecturette on the work done by the Section of Zoology during the Pan-Pacific Science Congress.

DECEMBER 5TH, 1923.

The four hundred and forty-third General Monthly Meeting was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. R. H. Cambage, President, in the Chair.

Forty-five members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificate of one candidate for admission as an ordinary member was read for the first time.

A letter was read from Mrs. J. R. L. Dixon, expressing thanks for the Society's sympathy in her recent bereavement.

The following donations were laid upon the table:—2 volumes, 125 parts, 4 reports, 1 map, and 1 calendar.

THE FOLLOWING PAPERS WERE READ:

1. "Acacia Seedlings," Part IX, by R. H. Cambage, F.L.S.
2. "The Essential Oil of *Backhousia angustifolia*," Part I, by A. R. Penfold, F.C.S.
3. "Some notes on Wattle Barks," by M. B. Welch, B.Sc., W. W. McGlynn, and F. A. Coombs, F.C.S.
4. "Plant Invasion of a Denuded Area," by R. H. Cambage, F.L.S.

Mr. C. A. Sussmilch and Professor Griffith Taylor delivered interesting lecturettes on the work done by the Section of Geography during the Pan-Pacific Science Congress.

GEOLOGICAL SECTION.

ABSTRACT OF THE PROCEEDINGS

OF THE

GEOLOGICAL SECTION.

Seven meetings of the Section were held during the year. The average attendance was eleven members and three visitors.

Annual Meeting, 16th April, 1923.

Professor Sir Edgeworth David in the Chair.

Twelve members and seven visitors were present.

Professor David was elected Chairman for the year, and Professor Cotton and Mr. L. L. Waterhouse were elected joint Honorary Secretaries.

EXHIBITS:

By Professor David—Diabase implements from Mount William, Tasmania. *Eurydesma cordatum* from Maria Island, Tasmania. Serpentine from the Zeehan-Railton Road, Tasmania. West Coast Conglomerate, Tasmania. Granite which intrudes serpentine, Tasmania. Diabase (which is intruded by Melilite basalt) Tasmania. Aboriginal weapons from the Lake Leake Cherts, Tasmania.

A lecture, illustrated by lantern slides, dealing with "Some Recent Advances in Tasmanian Geology," was given by Professor David. The lecturer gave an account of some of his researches into the problems of the Pleistocene Glaciation in Tasmania. He showed that certain glacial deposits (moraines) in the Pieman and Henty valleys which were previously referred to the Permo-Carboniferous glacial period were undoubtedly much younger and should probably be classed as belonging to the Günz or perhaps the Mindel glacial period of the Northern Hemisphere. Certain gravels near Strahan which were previously regarded as raised beaches are now recognised as outwash apron gravels from the glaciers of the moraines above mentioned. Certain shattered beds of Permo-Carboniferous shales and sandstones associated with the moraines owe their origin to ice pressure. At Penguin certain deposits at first regarded as glacial were subsequently shown to be due to a large crush zone associated with heavy faulting.

A vote of thanks was carried by acclamation.

Monthly Meeting, 11th May, 1923.

Professor David in the Chair.

Fourteen members and three visitors were present.

EXHIBITS:

1. By Mr. Raggatt—Phosphate rock containing fossil egg, from Ocean Island.

2. By Mr. G. W. Card, (exhibit introduced by Mr. Willan) —Zirkite, a refractory substance withstanding extremely high temperatures, found only in Brazil.

3. By Mr. Osborne—Diatomaceous earth with dicotyledenous leaves from Wyralla. Vesicular basalt with chalcedony amygdules which overlies the Wyralla diatomaceous earth.

Mr. C. A. Sussmilch after suggesting a preliminary discussion in the section of problems for the Pan-Pacific Science Congress, gave a summary of his Presidential Address to the Society "The History of Vulcanism in New South Wales," illustrated by several typical geological sections. He particularly stressed the Tertiary activity, calling attention to his classification into the Alkaline Series, Plateau Basalts and Monadnock Basalts, pointing out that he was guided mainly by physiographic considerations in making the classification.

In the discussion which followed, a number of members took part.

Dr. Browne emphasised the tremendous field for petrological research, not only in the Palæozoic but also in the Tertiary rocks, quoting various New South Wales localities in support of his contention. He rather questioned the validity of physiographic evidence in correlating Tertiary flows.

Professor Cotton considered that physiographic evidence was of value in establishing the relative ages of the Tertiary flows.

Professor Taylor stressed the value of cycles of erosion.

Mr. Osborne referred to the intrusions near Sydney and pointed out the similarity of the inclusions with those described by Dr. Jensen from the Nandewar Mountains.

Mr. Mann agreed that further work was necessary in the Yass district before finality could be reached.

Mr. Raggatt discussed the Bowning Hill section in relation to the igneous suite of rocks.

Mr. Willan pointed out that the presence of tuffs showed that volcanic activity continued throughout the Narrabeen stage, and part of the Wianamatta stage of the Triassic.

Professor David discussed the problems presented by the Jenolan and Yass igneous rocks, and pointed out that the Mesozoic volcanic activity as indicated by abundant tuffs in the Narrabeen and Wianamatta series, had not been generally recognised. He discussed the age of the necks of the Sydney district and urged a detailed study of the enclosed plant remains. With reference to the age of the basalts, he stressed the importance of a study of the plant remains of the deep leads and a possible correlation with the Victorian basalts, the age of which may be fixed with relation to the Tertiary limestones. He suggested that the Tayan Peak crater described by Carne might be as late as Pleistocene.

Mr. Sussmilch briefly replied to the various questions raised during the discussion.

Monthly Meeting, 8th June, 1823.

Dr. W. R. Browne in the Chair.

Nine members and three visitors were present.

Correspondence—An extract from a letter from Sir Douglas Mawson was read in which he thanked the Section for their congratulations on his election as a Fellow of the Royal Society of London.

EXHIBITS:

1. By Mr. L. L. Waterhouse—Decomposed granite from a quarry at Sodwalls fused by explosion in which Rack-a-Rock was used.

2. By Mr. Osborne—Quartz crystals intergrown in the form of a cross.

3. By Mr. Raggatt—Specimens of asbestos from South Africa.

4. By Mr. Smith—Dematoid garnet and Nesquionite from Serpentine from the Italian Alps. Topaz in granular quartz from Torrington.

5. By Mr. Dun on behalf of Mr. Mitchell—Concretions showing asymmetrical development about a fracture plane. *Omphalotrochus (Euomphalus) Clarkei* from Yass. Shale showing fine lamellæ. Pebbles showing minute faulting.

Mr. Mitchell was accorded a vote of thanks forwarded through Mr. Dun.

6. By Dr. Browne—*Eurydesma hobartense* from below the plant-horizon of the Lochinvar Shales. The matrix is

a mudstone similar to the Lochinvar Shales. Mr. Dun considered this a distinctly Permian type.

Mr. L. L. Waterhouse contributed a paper reviewing and summarising the recent work of Stopes and Wheeler with regard to the Constitution of Coal. The lecture was illustrated by physical and chemical tests carried out by Mr. Waterhouse on New South Wales coal. These tests confirmed the results obtained by Stopes for English coals.

Mr. Waterhouse emphasised the need and great opportunities for research along these lines in connection with our Australian coals. The paper was discussed by Dr. Cotton, Mr. Raggatt, Mr. Grutzmacher, Mr. Taylor and Dr. Browne. Mr. Waterhouse then replied.

Monthly Meeting, 13th July, 1923.

Mr. C. A. Sussmilch in the Chair.

Ten members and six visitors were present.

The Chairman on behalf of the Section congratulated Professor Browne on his recent promotion to the position of Assistant Professor at the University.

The Section also expressed its deep sympathy with Mr. E. C. Andrews in his recent bereavement.

EXHIBITS:

1. By Professor Taylor—A fine photograph of the Kanimbla Valley taken from the Jenolan Caves Road.

2. By Mr. T. H. Smith—Rutile from Grenfell (a new locality for N.S.W.) Wollastonite in the form of reddish-brown tabular crystals in galena.

3. By Mr. C. A. Sussmilch—Photographs of a fossil tree (*Dadoxylon*) from a road cutting about three miles west of Scone. The roots are preserved and the tree is apparently in its position of growth.

The chief business of the evening was a discussion of Professor Taylor's paper on "The Warped Littoral around Sydney."

Professor Taylor opened the subject by an amplification of his paper as read before the last general meeting of the Society. He illustrated his paper by lantern slides and diagrams.

The discussion was opened by Mr. C. A. Sussmilch who pointed out the similarity of the sediments about Windsor and Richmond, which Professor Taylor regarded as lacustrine deposits, to the flood plain deposits preserved in the terraces of the Hunter River Valley.

Mr. Sussmilch also discussed the form of the Blue Mountain valleys which he thought could be explained adequately by the sapping of the underlying weak strata of the Permo-Carboniferous Coal Measures. He also referred to the river gravels underlying the basalt residuals at Mount Tomah and Mount Wilson, and regarded these as evidence that the former drainage was like the present from West to East.

Professor Cotton raised the question as to the relative ages of the high level gravels about Penrith and Windsor and the lake silts described by Professor Taylor.

Professor Browne suggested that the term "maiden plateau" might be more appropiate than the term "core" used by Professor Taylor. He pointed out that elevations of about 200 feet occurred in the "region of uplift" described by Professor Taylor about Cook's River. He also suggested the alternative of a hard bar instead of a post-Nepean warp as a possible explanation of the silt deposits about Windsor and Richmond. Another problem which he raised was the relation of the Wianamatta Stillstand to the 200 feet submergence along the coast of the Sydney area.

Mr. Poole suggested that the warping of the coastal strip might still be in progress and stated that certain adjustments which had been made on the Observatory telescope suggested that a tilting movement might be in progress.

Mr. Osborne thought the silt deposits about Wallachia and at Windsor and Richmond might be due to flood plain deposition and not to lacustrine conditions. He pointed out that in the Arncliffe district a relief of 150 feet was present.

Mr. Willan who was unable to be present forwarded a written contribution to the discussion. This was read by the Secretary.

Professor Taylor in reply raised the question as to what alternative hypothesis could be advanced to explain the origin of Botany Bay if the region of no uplift was not accepted. He also pointed out that the development of lakes in the Nepean Valley depended on the rate of cutting of the rising warp to the north. In conclusion he explained more fully some of the terminology used in his paper.

Monthly Meeting, 12th October, 1923.

Mr. R. H. Cambage in the Chair.

Six members and two visitors were present.

EXHIBITS:

1. Limestones with Silurian corals from near Tarago.

2. By Mr. McKern (*a*) A new australite from near Mount Hope found at a depth of three feet in the alluvium of an old lake bed. (*b*) A basalt from New England exceptionally rich in olivine. (c) Specimens from the border of Queensland and New South Wales showing a desert varnish consisting of sulphide of iron.

A paper was read by Mr. Sussmilch dealing with the Physiography of Eastern N.S.W. Special attention was devoted to the significance of the Upland Valleys which are often several miles in width with heavily aggraded floors and a valley relief of from 200 to 250 feet.

Two high level terraces at about 150 and 400 feet above sea level were recorded from the Hunter River District.

Mr. Sussmilch's paper was discussed by Mr. Cambage, and Professors Browne and Cotton.

Mr. Cambage thought that the Bathurst area did not exhibit much evidence of heavy faulting.

Professor Browne discussed the physiography of the Cooma district which he stated showed evidence of an original north flowing river system. He suggested that the Tertiary basalt flows may have been responsible for some alteration of the pre-existing drainage systems and that tectonic movements might be of less importance than suggested by Mr. Sussmilch. He also questioned the application of the term "stillstand" to the area occupied by the Wianamatta shales.

Mr. Sussmilch replied stressing the importance of physiographic criteria for faulting and explained that the term "stillstand" as applied to the Wianamatta area was used only in a relative sense.

Monthly Meeting, 9th November, 1923.

Mr. C. A. Sussmilch in the Chair.

Nine members and two visitors.

EXHIBITS:

1. By Mr. L. L. Waterhouse—Devonian intrusive tuff from Chichester Dam.

A paper was read by Mr. E. C. Andrews dealing with "The Form of Ore Bodies characteristic of the Zones of Flowage and Fracture." Mr. Andrews dealt first with the form of igneous masses above the zone of flowage. He discussed the influence of the force of crystallisation in wedging apart the rock masses in the case of sills and dykes. He regarded laccolites and batholiths as special cases of gigantic sills. The saddle reefs are a characteristic form of ore body in the zone of fracture.

In the zone of flowage the igneous intrusives are in the form of sills only. The ore bodies in the zone of flowage were illustrated by reference to the Broken Hill and the Black Hill deposits. He pointed out that these ore bodies are in the form of sills developed as replacements along lines of crush. The ores entered by passing through bodies of rock leaving no trace of entry.

Discussion:

Dr. Woolnough stated that his observations on the rocks of the zone of flowage in Western Australia supported the view of Mr. Andrews that batholiths do not occur in the zone of flowage.

Dr. W. R. Browne considered that the ores at Broken Hill may have been formed during the plastic stage and may have been nipped off in the process. He raised the question as to whether the sill is typical of the zone of flowage and pointed out that it is characteristic of the zone of fracture.

Mr. L. L. Waterhouse and Dr. Cotton also contributed some remarks.

Mr. Andrews in reply regarded the Broken Hill pegmatites as the forerunners of the ore bodies; they sweated through the country rocks and were afterwards replaced by ores. Consequently the ore bodies are not nipped off but were developed after the faulting, folding and crushing.

He also referred to discrepancies between the maps and sections illustrating some of the West Australian reports. In the maps the igneous masses exhibit sill structure, but in the sections these are interpreted as batholiths.

Monthly Meeting, 14th December, 1923.

Professor David in the Chair.

Seven members were present.

EXHIBITS:

1. By Professor Cotton—(*a*) Artifacts from Wilcannia. (*b*) Crystals of sandbarite from Hallet's Cove, S.A.

2. By the Mining Museum—Australites from Western Australia.

3. By Professor W. R. Browne—(*a*) Intrusive Tertiary Dolerite from Savoy Trig. Station ten miles south-west of Muswellbrook. (*b*) Devonian quartzite with rounded stem-like marks parallel to the bedding planes.

4. By Dr. C. Anderson—The palate and teeth of *Nototherium Mitchelli* from Borenore.

General Business.

A paper was given by Mr. W. S. Dun on "The Classification of the Permo-Carboniferous Rocks of Queensland." Mr. Dun after his recent examination of the fossils at Brisbane, concludes that the type Gympie beds are the equivalents of the Lower Marine in New South Wales and that the Warwick and Silverdale beds are of the same age. In the early work the only fossils available were highly altered and distorted, so that *Productus cora* was described as *Leptœna* and *Chonetes* as *Orthis*. It was on these determinations that Etheridge considered the Gympie beds to be of Devonian age. Another correlation is furnished by the occurrence in the Gympie beds of a well developed *Fenestella* and *Stenopora* horizon similar to that at Pokolbin in New South Wales. The Bowen Coalfield is not continuous with the Gympie beds but the sequence of the formations is similar to that in New South Wales. At Bowen there is a fresh water series of coal measures equivalent to the Newcastle-Tomago beds. Below this is a marine horizon containing *Martiniopsis*, *Chaenomya* and *Maeonia* but with no *Eurydesma*. This is the equivalent of the Upper Marine Series of New South Wales. Below this marine series is another series of coal measures with anthracite and these beds in general rest on a volcanic series. At Springsure, Jensen has described marine beds with *Eurydesma cordatum* overlying coal measures which he therefore considers to be much below the Greta horizon in New South Wales. Mr. Dun, however, points out that the species is not *Eurydesma cordatum* but *Eurydesma hobartense* and that the coal seams below these marine beds are therefore probably of Greta age. There is a marked unconformity between the Upper Coal measures and the Upper Marine series.

Discussion:

Professor David reviewed the recent work of Dr. Jensen and Professor Richards on the Permo-Carboniferous rocks of Queensland, and pointed out that the exaggerated vertical scale in the published section of the Bowen River Coalfield was misleading, as it unduly emphasised the unconformity (if any) between the Upper and Lower Bowen Coal Measures.

Dr. Woolnough discussed the marine beds in the Wingham-Taree area which Mr. Dun regards as being of Lower Marine Age.

SECTION OF AGRICULTURE.

ABSTRACT OF THE PROCEEDINGS
OF THE
SECTION OF AGRICULTURE.

Annual Meeting, 14th May, 1923.

Professor R. D. Watt in the Chair.

The election of officers resulted as follows:—Chairman—Professor R. D. Watt, M.A., B.Sc., Vice-Chairman—Professor J. D. Stewart, B.V.Sc., M.R.C.V.S., Honorary Secretaries—P. Hindmarsh, M.A., B.Sc. Agr., R. J. Noble, M.Sc., B.Sc. Agr. Committee—S. Dodd, D.V.Sc., F.R.C.V.S., A. D. Ollé, F.C.S., W. L. Waterhouse, M.C., B.Sc. Agr., D.I.C., E. A. Southee, O.B.E., M.A., B.Sc. Agr.

Pending the return of Mr. Noble, Mr. W. L. Waterhouse agreed to act as Secretary.

The Chairman spoke upon the forthcoming Pan-Pacific Science Congress with special reference to the Agricultural Section.

Monthly Meeting, 11th June, 1923.

Professor R. D. Watt in the Chair.

Dr. Elwood Mead spoke upon "How is future land settlement in America to be financed." Dr. Mead told the story of the land settlement scheme at Durham, California, and the deductions drawn from that Experimental Settlement.

Monthly Meeting, 9th July, 1923.

Professor R. D. Watt in the Chair.

Dr. Darnell Smith spoke upon "Bunchy Top Disease of the Banana." Dr. Smith outlined the results of the investigations to cope with this disease, that had so far been made. (*a*) The disease was apparently not due to deterioration following upon continued vegetative reproduction. (*b*) No results had been obtained from soil analyses, or manurial trials. (*c*) No definite causal organism had been isolated. (*d*) Trials with sprays had given no results. Dr. Smith also discussed the blue mould of tobacco (*Peronospora hyoscyami*).

Mr. Shelton exhibited samples of wheat grains grown at Coonamble, varying in their yield, and in their reactions to rust. On black soils the yields per acre were as follows:—Sunset 4 bushels 8 lbs.; Gressley 5 bushels 24 lbs.; Hard Federation 5 bushels 25 lbs.; Bunyip 4 bushels 8 lbs.; Canberra 8 bushels 8 lbs.; Clarendon 10 bushels 8 lbs. In many cases the grain was badly pinched, probably due to the rust utilising the water of the plant, and so interfering with the transpiration stream.

Mr. W. L. Waterhouse exhibited (*a*) Two subspecies of maize *Zea amylacea* and *Zea mays tunicata;* (*b*) French beans suffering from Anthracnose and Isariopsis; (*c*) A seedling of Yandilla King wheat, which showed the appearance of two first leaves from the one grain.

Monthly Meeting, 10th August, 1923

Professor R. D. Watt in the Chair.

Dr. Babcock of California University spoke upon "Species hybrids and their bearing upon Evolution." After revising the underlying theories, the speaker referred to his work at California upon "*Crepis.*" This work consisted of making taxonomic studies of the species, crossing the various species, and making genetic studies of the species and the resulting crossbreds.

Monthly Meeting, 17th September, 1923.

Professor R. D. Watt in the Chair.

Dr. Stakman of Minnesota spoke upon "Wheat Growing in the United States of America." The types and varieties of wheats used in the United States of America were discussed. The four factors controlling wheat growing in that country were elaborated, viz., (*a*) soil factor, (*b*) climatic factor, (*c*) economic factor, (*d*) the biologic factor. Climatic cataclasms were not uncommon and did considerable damage. Wheat growing as a single crop was giving way to mixed farming. The rust problem was discussed, with special reference to the "Barberry" as a host to that serious disease.

Monthly Meeting, 8th October, 1923.

Professor R. D. Watt in the Chair.

An excursion to the Port Kembla Works of the Australian Fertiliser Proprietary Company was announced.

Dr. R. J. Noble spoke upon "Flag Smut." Flag Smut in the aggregate does more damage than rust, ranging from 3 to 25% of the crop being destroyed. The damage was apparently on the increase. Dr. Noble had been specially concerned with the spore germinations. His successful attempts by using plant tissues and various volatile substances as benzaldehyde were discussed. Some practical suggestions for the farmer were detailed.

Monthly Meeting, 12th November, 1923.

Professor R. D. Watt in the Chair.

Principal Southee spoke upon "Genetics of Maize." He discussed the various results obtained in the studies of the Emmerson School of Maize Geneticists. Suggestions concerning practical maize breeding concluded the address.

Monthly Meeting, 12th December, 1923.

Professor R. D. Watt in the Chair.

Dr. Seddon spoke upon "Forage Poisoning (Botulism); the Evolution of a Research." The speaker traced the development of knowledge from that of a disease causing staggers in animals with special symptoms of salivation and inability to apprehend food, to that of the recognition of three forms caused by distinct organisms, viz., *B. botulinus* (two forms) and *B. para botulinus.*

The relation to bone chewing was shown.

Dr. Fiaschi exhibited maize plants grown at Sackville Reach. They were planted on February 11th, 1923 and cut for grain on June 27th, 1923—a period of 136 growing days.

Mr. W. L. Waterhouse exhibited (*a*) A sectorial chimera in *Polygonum aviculare;* (*b*) Specimens of *Ægilops, Triticum dicoccum dicoccoides,* and *Triticum spœro-coccum.*

Committee Meetings—Seven Committee meetings were held during the year. The following attendances were recorded:—Professor R. D. Watt 7, Professor J. D. Stewart 3, Dr. S. Dodd 1, Mr. A. D. Ollé 7, Mr. W. L. Waterhouse 7, Mr. A. E. Southee 4, Mr. P. Hindmarsh 6, Dr. R. J. Noble 2.

SECTION OF INDUSTRY.

ABSTRACT OF THE PROCEEDINGS

OF THE

SECTION OF INDUSTRY.

Committee Meeting, 16th May, 1923.

It was decided to discontinue the usual meetings of Committee and have pre-lecture meetings of all members of the Society interested in the work of the Section.

General Meeting—Mr. A. D. Ollé in the Chair.

Mr. R. Farquhar Boan of the Borthwick Proprietary gave an address upon "Paints" in which he discussed the various ingredients such as oils, pigments, fillers and thinners which go to make a paint. Their sources, properties and uses were described, and many specimens and lantern slides helped to illustrate his points.

Pre-Lecture Meeting, 20th June, 1923.

Mr. George Wright was unanimously elected Chairman of the Section for 1923. Dr. Greig-Smith was re-elected as Hon. Secretary.

General Meeting—Mr. George Wright in the Chair.

Mr. A. Dickinson of S. T. Leigh and Co. gave an address upon "Printing upon Metals," in which after an historical survey, he described the modern methods of transferring drawings and paintings from paper to stone and from stone to rubber and then to metal.

General Meeting, 18th July, 1923.

Mr. George Wright in the Chair.

Mr. A. H. Varcoe, B.Sc. of Davis Gelatine (Aust.) Ltd., gave an address upon "Industrial Glue and Gelatine" in which he described the manufacturing processes leading from the raw skins, sinews and fleshings up to the finished glue and gelatin. Then followed a résumé of the various uses to which the varieties of glue and gelatine are put. The different qualities of glue are used for adhesives by various industries while gelatine finds a use in the making of chocolates and sweets as well as in the electrolytic deposition of zinc.

General Meeting, 15th August, 1923.

Mr. George Wright in the Chair.

Mr. R. D. Toppin of Parke, Davis and Co. gave an address upon "Glandular Products" in which he discussed the various glands of the animal body that are used for medicinal purposes, the methods whereby they are made into standard preparations and the effects which they produce. It was stated that insulin about which the public was then interested was still in the experimental stage and would be of little use until it could be obtained as a powder for oral administration.

General Meeting, 19th September, 1923.

Mr. J. E. Bishop in the Chair.

Mr. S. J. Young, B.Sc., B.E., of Metal Sprayers Ltd., gave a lecture upon "The Schoop Metal Spray." By means of the lantern, he traced the gradual development of the invention whereby a wire of metal is volatilised and blown upon clean surfaces to which it adheres. Many metals may be utilised and almost any surface which is dry and clean can be coated with a film; for example glass can be coated with copper or brass, and huge iron and steel structures can be coated with zinc.

General Meeting, 17th October, 1923.

Mr. George Wright in the Chair.

Mr. Richard Harding of the British Australian Cotton Association gave an address upon "The Cotton Industry in Australia." The world's shortage of six million bales made the mills of Lancashire apprehensive as to the future of the industry. Their mills are adapted to work only the finest qualities which come from America and Egypt, and as the supply from these sources is limited, there is a great opportunity for the Australian industry. Australia with its present population is capable of supplying one and a half million bales. The soil and climate of the Australian Cotton Belt gives an average yield of 800 lbs. per acre (higher than the American) and the lint realises from 1½d. to 2d. per lb. more than the American.

General Meeting, 21st November, 1923.

Mr. J. E. Bishop in the Chair.

Mr. E. W. Wills of Messrs. Elliott Bros. exhibited some new forms of chemical apparatus.

Mr. R. Farquhar Boan of the Borthwick Proprietary gave an address upon "Varnishes," in which he described the various resins or gums and their uses in the preparation of spirit and oil varnishes. The linseed oil is clarified by heating at 500° when the calcium and aluminium phosphates are thrown out of combination. The clarified oil is boiled with the fossil gums and the varnish is improved by the addition of small quantities of driers such as the resinates of lead, manganese and cobalt, and is thinned by the addition of turpentine and turpentine substitutes.

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